MCR-70-89 (Vol I) Copy No. 5

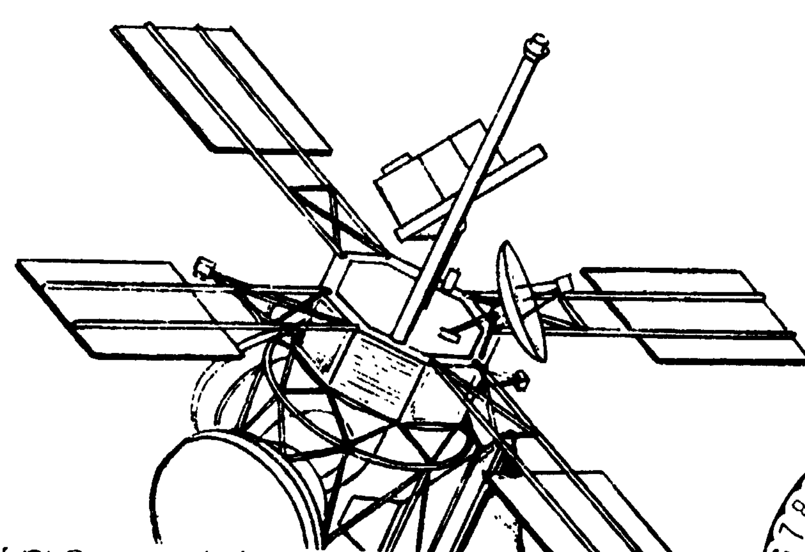
CONTRACT JPL 952534

1975 VENUS MULTIPROBE MISSION STUDY

FINAL STUDY REPORT

VOLUME I
INTRODUCTION, SUMMARY, CONCLUSIONS

APRIL 1970



MARTIN MARIETTA CORPORATION

MCR-70-89 (Vol I)

Contract JPL 952534

1975 VENUS MULTIPROBE MISSION STUDY

FINAL REPORT

March 1970

Volume I

INTRODUCTION, SUMMARY, CONCLUSIONS

Approved

Stephen J. Ducsai,
Study Manager

MARTIN MARIETTA CORPORATION
Denver Division
Denver, Colorado

FOREWORD

This report has been prepared in accordance with requirements of Contract JPL 952534 to present data and conclusions resulting from a six month study effort performed for the Jet Propulsion Laboratory by the Martin Marietta Corporation. Volume I contains the Introduction, Summary and Conclusions, Volume II contains details of the Technical Studies and Analysis, and Volume III contains the Appendixes.

CONTENTS

VOLUME I - INTRODUCTION, SUMMARY AND CONCLUSIONS

ACKNOWLEDGMENT

The following individuals have participated in the conduct of this study and their efforts have been greatly appreciated.

Stephen J. Ducsai	- Study Leader, Program Manager
Allen R. Barger	- Science, Lead
Edward B. Burton	- Systems Engineering
Patrick C. Carroll	- Aerodynamics
Douglas B. Cross	- Mission Analysis, Lead
Paul A. Dillard	- Power
Robert B. Fischer	- Mission Analysis
Joseph F. Harcarufka	- Telecommunications
Dennis W. Holst	- Antennas
Tim H. Kelley	- Attitude Control
Robert K. McMordie	- Thermal Control
John R. Mellin	- Structural/Mechanical Lead
Frank H. Nicholson	- Mechanical Design
Jack D. Pettus	- Data Systems
Paul G. Reznicek	- Mechanical Design
Robert J. Richardson	- Telecommunications, Lead
Bruce G. Schelden	- Thermal Control
Robert W. Stoffel	- Mission Effectiveness
William A. Swank	- Propulsion
David Waddington	- Power
Ludwig G. Wolfert	- Science Integration
Raymond G. Ziehm	- Mission Effectiveness and Systems Engineering, Lead

I. INTRODUCTION

The material presented in this report summarizes efforts and products of a six-month study of a 1975 Venus multiprobe entrv mission for atmospheric exploration. Included are the results and conclusions of the study, the system and subsystem trades considered, and the definition of a baseline mission with two separate science capability improvement options.

The fundamental study objectives were to identify the number and capability of entry systems required to accomplish the science mission, and to integrate the specific instruments into probes and complete missions. The science objectives for the mission were predefined in the form of 18 questions to be answered regarding the Venus atmosphere. These questions may be grouped into four major categories as follows: cloud composition and distribution, atmospheric circulation, atmospheric composition and structure, and upper atmosphere structure.

The scope of the study included three major task areas: trajectory definition, entry probe definition, and Planetary Vehicle definition. The level of detail in entry probe and Planetary Vehicle design was limited to that required to determine system configuration and operation, to make proper mission selections, and to identify development or technology requirements. Limitations were also placed on technology and design approaches for the entry probes and spacecraft, which were to use the concepts presented in AVCO Report AVSSO-080-68-RR.*

**1975 Venus Flyby/Entry Probe Mission Study*. Final Technical Report, Book I and II. AVCO Report AVSSO-080-68-RR. April 1968.

Consideration of the specific science capability of the Mariner spacecraft was not a study requirement although upper atmospheric measurements (preentry) were included, as discussed in Chapter I of Volume II.

Major constraints on the mission and study include the use of a Titan IIIC launch vehicle, 1975 launch date, and consideration of both a direct impacting and a flyby spacecraft mission. Direct to earth communications were required, and were to be compatible with the projected capability of the deep space network. The science instruments to be used were as defined in Appendix B-1, Volume III. All system and subsystem design was to utilize July 1972 state of the art. A complete list of constraints and requirements is presented in Appendix I, Volume III.

The study was accomplished in two major phases: (1) trial mission selection and definition, and (2) the baseline mission selection and definition.

The trial mission phase included the selection of a mission to be configured early in the study to identify potential trouble areas so that more attention could be focused upon them. This mission selection was accomplished without the benefit of detailed mission effectiveness studies that were conducted later and at no time was considered optimum or a recommended mission. Concurrent with this effort, parametric studies in trajectories, thermal control, and communications were pursued. The science objectives were converted to parameters that could be measured with the specified instruments, and a mission effectiveness model was written to aid in evaluating the capability of each mission toward measuring those parameters.

The baseline mission definition phase began with careful evaluation of the trial mission results that were used in the selection of the baseline mission and options to be configured. The remainder of the study was devoted to completing the definition of the baseline systems and evaluation of their capability.

The report is arranged so that Volume I (Introduction, Summary and Conclusions) will provide a broad understanding of activities, trades, and results of the study in a concise form, while Volume II (Technical Studies and Trades) presents the detailed analysis and configuration data for each technical discipline and mission approach. Configuration and operational data for the baseline mission and two options are presented.

Volume III (Appendixes) contains detailed data used and generated during the study.

II. SUMMARY

A. GENERAL

This report presents the data and conclusions of a study to determine the quantity, type, and targeting of multiple entry probes deployed from one spacecraft to conduct an extensive exploration of the Venus atmosphere. The study was to use a configuration of the 1969 Mariner spacecraft previously modified for a Venus application. Modifications beyond this were to be limited only to those necessary to accomplish this mission. A complement of science instruments was defined in the contract statement of work and was to be used for the collection of data to answer specific science questions. See Appendix B-1 (Vol III) for these detailed science objectives.

The atmospheric models used in the study and the regions of most importance to the science objectives are shown in Fig. 1. The upper atmosphere objectives require coverage down to about 6180 km just below the peak electron density in the ionosphere at 6192 km. The regions of most interest for the cloud and circulation measurements extend from above tne cloud tops down to 6085 km (the lower limit of the Mariner data), while the regions of most interest for the atmospheric structure are above and below the Venera data (from above the clouds to about 6100 km and from about 6175 km down to the surface).

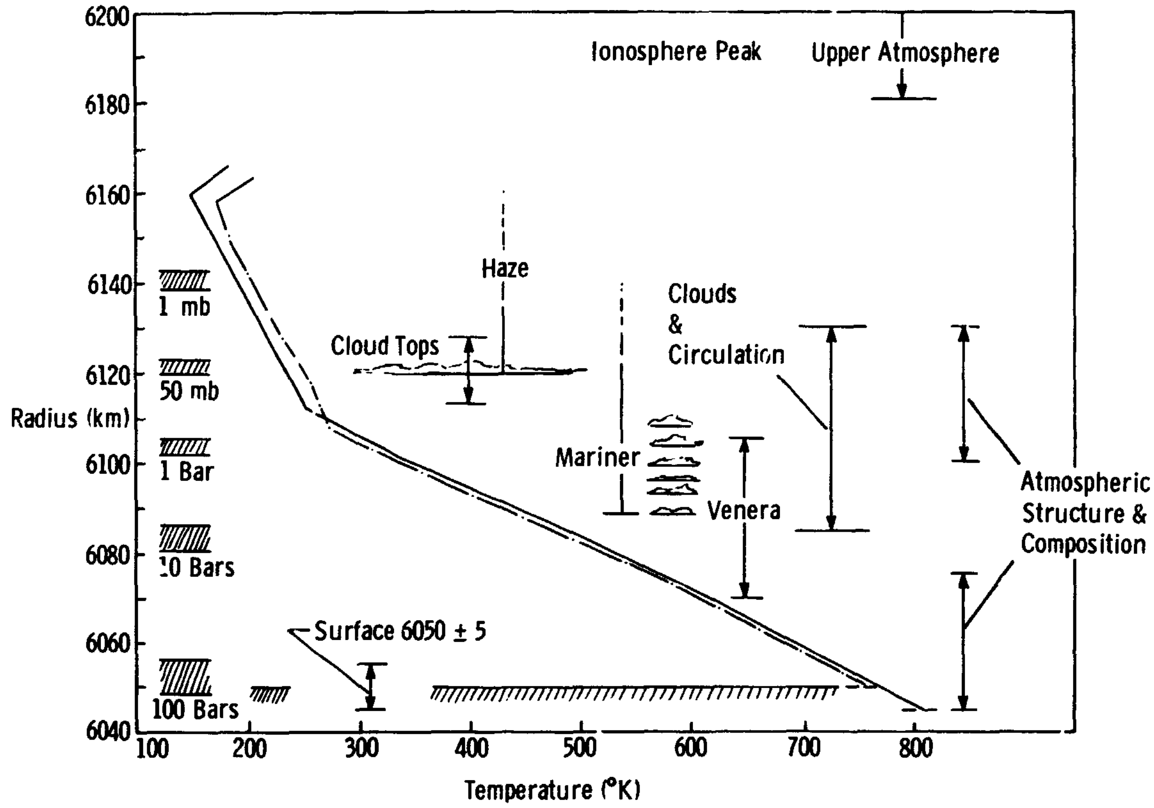


Fig. 1 Venus Model Atmosphere Used for the Study

The approach used to achieve study goals was to relate all configurations and operating modes directly back to the science objectives. This was done by carefully reviewing the science questions, some of which were general in nature, and to determine a method by which the available instruments could be used to provide an answer. This method included considerations such as the instruments (and alternatives) required, the target zone on the planet, and the altitude at which data should be gathered. This provided the basis on which all mission and study criteria would rest, and as mission evaluation techniques were developed, it became the basic reference used to measure mission capability.

As the science objectives were defined, efforts were underway to convert them into engineering systems and subsystems language, by means of a criteria document. In response to a JPL and GSFC suggestion the initial criteria document was directed toward the definition of a "trial" mission, selected in the early weeks of the study. The trial mission concept was to initiate subsystem design studies that could be started before completion of the science instrument/site/altitude studies, and thereby identify all design areas that might require special attention. The trial mission criteria document was used for all system and subsystem studies and provided a common configuration and operational goal. It served to identify mission objectives, constraints, operating sequences, and the interface requirements between subsystems, and between the probes, spacecraft, and launch vehicle.

Early in the program two additional efforts were also being worked concurrent with the science studies. The first of these was the generation of flight mechanics data in parametric form for the interplanetary, approach, and descent phases of the mission. The second was the development of a model that could relate the science capability of any particular mission to the science objectives, thereby providing a relative measure of mission effectiveness. These efforts were not tied to the trial mission although they aided in its final definition.

The trial mission was defined and the results presented at the midterm oral briefing. Thereafter all study effort was directed toward selection, definition, and evaluation of a "baseline" mission, including two science capability improvement options. Although the trial mission had been considered only as a direct-impacting-spacecraft mission, the baseline studies considered both a flyby spacecraft and an impacting spacecraft as required.

B. SCIENCE OBJECTIVES AND OBSERVABLES

The science objectives for the 1975 Venus Multiprobe Mission Study were contained in JPL Section Document 131-03* in the form of three questions:

1) What is the composition of the atmosphere?
2) What is the distribution and chemical composition of the clouds?
3) What is the general circulation pattern of the atmosphere?

These three questions were further divided into 18 subquestions, some of which required the formation of theories that could properly be based only on the data to be obtained from the mission. For example, the question, "Is the high surface temperature due to a greenhouse effect, to convective heating or to what effect?" requires the instrumention of the mission to prove or disprove two stated theories as well as one or more unstated theories. A more straightforward approach appeared to be the restatement of the three basic questions in terms of all the phenomena that should be measured as a prerequisite to the formation of such theories. As a result, 22 observable questions were written which formed the measurement objectives for the study. Each question is of such a form that the available instruments required are capable of providing an answer. No theoretical modeling is required, only the observation of an observable phenomenon.

**Science Criteria for Venus Entry Mission.* JPL Section Document 131.03. (Appendix B-1)

Appendix B-1 identifies the science criteria, and also contains a description of the science instruments available for the use of the study. Table 1 lists the 22 observables, preceded by a measure of the pressure/altitude reference obtained. These observables in themselves are insufficient to satisfy science objectives. Each observable is simply a statement of a phenomenon to be measured. The full objective must qualify that measurement with a description of where, both vertically and horizontally, and how often the measurement should be made. Appendix D (Volume III) provides these qualifications in the form of a set of curves giving the value or proportion of the observable measured as a function of how far the measurement was made from the desired location and how often it was made compared to the requirement.

An order of priorities was assigned by JPL concerning various categories of science objectives. These priorities, listed below, were not to be used for the purpose of excluding any instruments from consideration:

1) Priority 1 - Cloud Composition and Distribution
Observable Objectives 5, 7, 12, 13, 14, 15, and 16;
2) Priority 2 - Atmospheric Circulation
Observable Objectives 6, 12, 20, and 21;
3) Priority 3 - Vertical Structure of the Atmosphere
Observable Objectives 8, 9, 10, 11, 17, 18, and 22;
4) Priority 4 - Upper Atmosphere
Observable Objectives 1, 2, 3, and 4.

Table 1 List of Observable Measurements

0.1	Determine the planetocentric radius (or altitude above a reference sphere) of the probe during the subsonic portion of its descent.
0.2	Determine the planetocentric radius of the probe during the supersonic/hypersonic portion of its descent.
1.1	Identify the ionic species present in the upper atmosphere and determine their number density profiles.
1.2	Identify the neutral gas constituents in the upper atmosphere and determine their number density profiles.
1.3	Determine the electron number density and electron temperature profiles in the upper atmosphere.
1.4	Determine the UV radiation flux profiles at several wavelengths.
1.5	Determine the number densities and sizes of any cloud or haze particles versus altitude above the main cloud top.
1.6	Determine the wind shear profiles above and through the tops of the main cloud deck.
1.7	Determine the composition of any cloud or haze particles above the main cloud tops.
2.0	Determine pressure, temperature and density profiles from above the clouds to the surface over several widely separated points on planet.
2.1	Identify the minor atmospheric constituents and determine their number density profiles.
2.2	Determine the precise ($\pm$0.5%) concentration of CO_2 at several altitudes between cloud tops and surface.
2.3	Determine the abundances and isotopic ratios of the rare gases, e.g., N_e^{20}, N_e^{22} , A^{36}, A^{38}, A^{40}, etc.
2.4	Locate the top of the visible cloud layer with respect to pressure, temperature, and radius over several widely separated points on the planet.
2.5	Locate (with respect to pressure, temperature, and radius) and determine the vertical extent of all cloud layers between the surface and cloud tops.
2.6	Determine the chemical composition of the cloud particles in each cloud layer.
2.7	Determine the number density and size distribution of the cloud particles versus altitude within each cloud layer.
2.8	Determine the physical state (liquid, solid) of the cloud particles versus altitude in each cloud layer.
2.9	Determine the visible radiation fluxes (direct, diffuse) at several wavelengths versus altitude over several widely separated points on the light side.
2.10	Determine the upward and downward thermal IR radiation fluxes at several wavelengths versus altitude over several widely separated points on the planet.
2.11	Determine the general circulation pattern of the atmosphere at several altitudes.
2.12	Determine the horizontal and vertical wind profiles near the subsolar and antisolar points and a pole.
2.13	Determine the magnitude and frequency spectrum of the turbulence versus altitude near the subsolar polar and antisolar points.
2.14	Search for transient light phenomena during descent.

C. ALTERNATIVE MISSIONS

1. Instrument Preference List

The major study objective was to determine the number and capability of entry probe systems required to provide answers to a specific set of scientific questions, using a specific list of candidate instruments. To make effective use of mission capability, the instruments that could provide an answer to each question were identified and reviewed to determine which instruments provided the most data for all questions. A new list was then compiled that identified the instruments in order of descending utility.

Table 2 shows the desired order and target zones for developing an instrument complement for the mission. Note that the first group of instruments is placed at subsolar, the second at the pole, and the third group back at subsolar. The significance of this is that the electron density, cloud composition, and cloud particle number-density and size measurements at subsolar, each contribute more science data than any instrument at the third target zone, antisolar. In each case when a new target zone is required, pressure and temperature are added first because they are basic to all measurements/questions.

The instruments at any site may be carried in one or more probes to provide proper sampling conditions; however, if a second probe is added, it will also include pressure and temperature measurements.

If this selection process were continued without regard to complexity, mission weight or the diminishing utility of additional instruments, the need for a fourth target site would soon evolve, and eventually the complete instrument candidate list would be included at each target.

Table 2 Preference List

Subsolar	Polar	Antisolar	Morning Terminator
Pressure Temperature 70-km Radar 1. UV Photometer 2. Mass Spectrometer			
	Pressure Temperature 3. Mass Spectrometer		
4. Electron Probe 5. Cloud Composition 6. Cloud No. Size			
		Pressure Temperature 7. Mass Spectrometer	
8. Solar Radiometer			
	9. Solar Radiometer		
10. Accelerometer 11. High Altitude Mass Spectrometer			
	12. Cloud Composition		
		13. Cloud Composition	
	14. Cloud No. Size		
		15. Cloud Size	
	16. Accelerometer		
17. Ion Mass Spect.			
		18. Accelerometer	
19. Thermal Radiometer			
	20. Thermal Radiometer		
		21. Thermal Radiometer	
22. Nephelometer			
	23. Nephelometer		
		24. Nephelometer	
	25. Drift Radar		
		26. Drift Radar	
27. Evap/Condens			
	28. Evap/Condens		
		29. Evap/Condens	
30. Transponder			
	31. Transponder		
		32. Transponder 33. Solar Radiometer	
			Pressure Temperature 34. Solar Radiometer
	35. UV Photometer 36. Electron Probe 37. Ion Mass Spectrometer		
			38. Accelerometer
	39. High Altitude Mass Spectrometer		
		40. Electron Probe	
			41. Electron Probe
		42. UV Photometer	
			43. UV Photometer
		44. Ion Mass Spectrometer	
			45. Ion Mass Spectrometer
		46. High Altitude Mass Spectrometer	
			47. High Altitude Mass Spectrometer

2. Mission Effectiveness Model

The many variables to be considered in arriving at the definition of a mission, and the many interrelationships between the observable objectives made it necessary to mechanize a scheme for comparing the mission descriptions and the objectives. The inputs to be considered fell into the two broad categories of science requirements and mission configuration description.

a. Science Requirement Inputs - The effectiveness of the mission in meeting the science requirements was evaluated as the result of five science inputs based, in turn, on the observable objectives.

The first input was a cumulative value profile that provided information on the desired altitude distribution of the data to be gathered for each observable. The profile itself varied in value from zero at an infinite radius to unity at the planet surface. The slope of the curve at any intermediate radius gave the relative importance of making a measurement at that point.

The second input was the instrument set required to answer the particular observable. The instrument set could assume any logical form, however in most cases one or more instruments were allotted proportionate shares of responsibility for providing the answer.

The third input was the required measurement interval. This interval was the required minimum distance, in kilometers, between successive measurements of an observable.

The fourth input was the target value curves that defined the relative value of the site at which a given measurement could be made.

The fifth and last input was the summation scheme to be used for the particular observable. More than one such scheme was required because some questions are basically answered by a single probe at a single target site, while others may require the measurement of a parameter at points distributed across the planet surface.

b. <u>Mission Configuration Inputs</u> - Information on the configuration of the mission was input to the model for comparison with the science requirements. The results of the comparison were then the science value obtained for the given observable. Five types of information are required for each probe.

The first input type was the target site location in terms of its latitude and longitude.

The second input was a descent profile for the probe in question. This profile was in the terms of the radius in kilometers versus the logarithm of the elapsed time in seconds.

The third and fourth inputs were the probe reliability and type, where the probe type distinguished between descent probes and balloon probes.

The fifth input was a list of instruments carried on the probe. For each instrument, two important pieces of information were required. The first was the radius, in kilometers, at which the instrument was turned on, turned off, or its sampling rate altered. The second set of information was the seconds between measurements of the given instrument.

c. <u>Operations of the Model</u> - The model compared the mission description including the probe input information and the information concerning each of the instruments on the probe with the five types of information that formed the science requirements implicit in the particular observable under consideration. The result of this comparison was a measure of the efficiency with which the

the mission answered the observable, or the question value. This question value was then allotted among the various probes and included instruments. As the question value was obtained for each observable in turn, a summation was made so that, finally, the model obtained a total mission value, a total value contributed by each probe and by each instrument. A simplified block diagram showing these operations is given in Fig. 2.

3. Mission Effectiveness Comparison

The effectiveness model was used to evaluate many mission configurations, some of which are presented in Fig. 3. The upper curve labeled "Instrument Preference List" identifies the value that can be achieved by the proper selection of any quantity of instruments under ideal conditions. One qualification must be made with respect to this curve. In its construction, an assumption was made concerning the altitude and pressure-temperature references that are used to determine the value obtained by a probe. It was assumed that the references had a value of unity when this is not generally true. Three hypothetical missions drawn from the preference list were actually evaluated by the model and a smooth curve labeled "Altitude Reference Degradation" passed through the three points. A lower curve labeled "Sampling and Targeting Degradation" is also plotted for the three hypothetical missions. The baseline mission and the two options to it are also plotted showing that these mission configurations lie very close to the extrapolation of this lower curve. A plot for the trial mission is found significantly below this curve, showing that the trial mission was not optimum.

The summaries of the various missions to follow are plotted in tabular form with the observables grouped together so that each of the four priorities can be visually integrated in judging the comparisons.

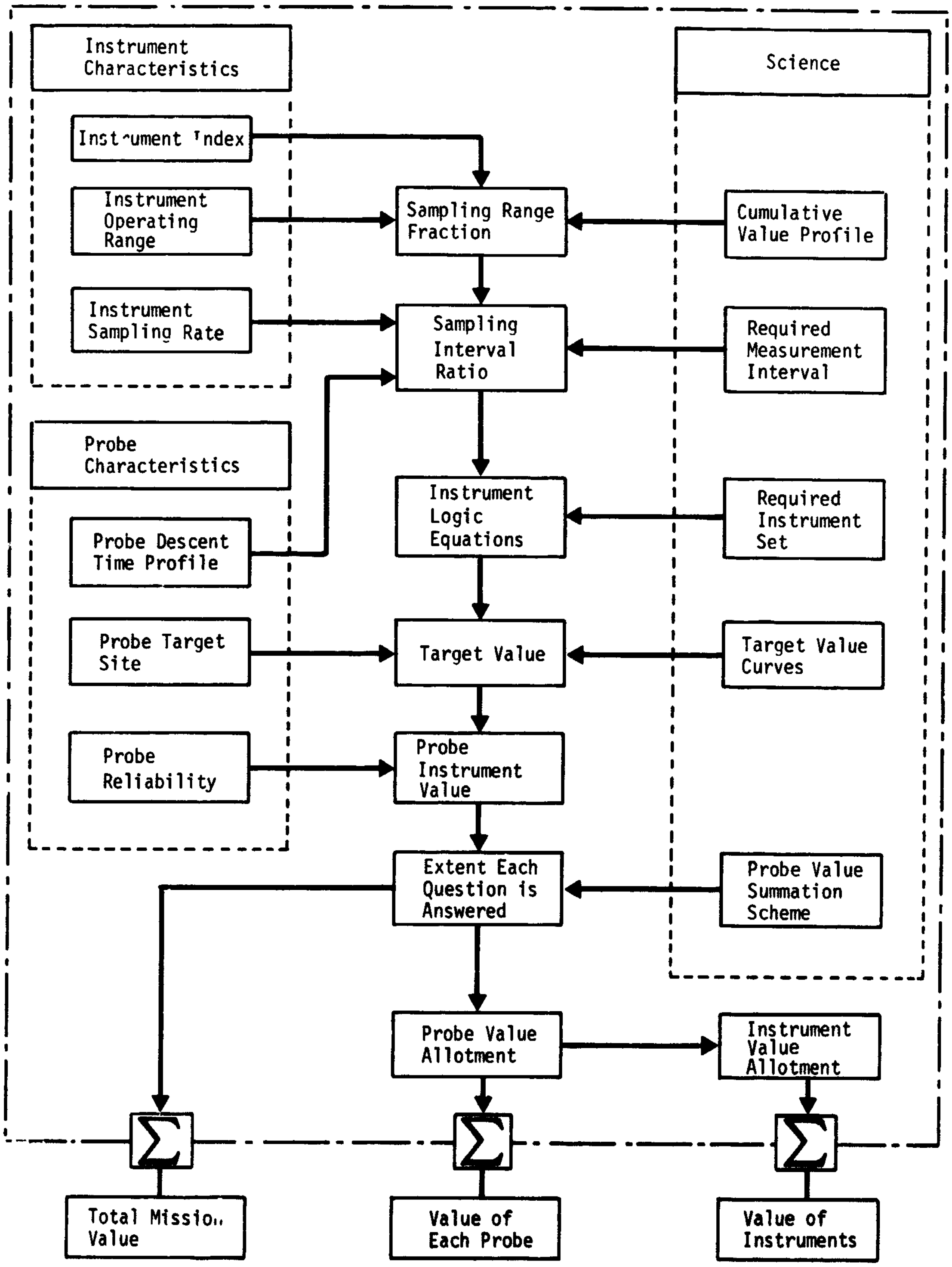


Fig. 2 Effectiveness Model Block Diagram

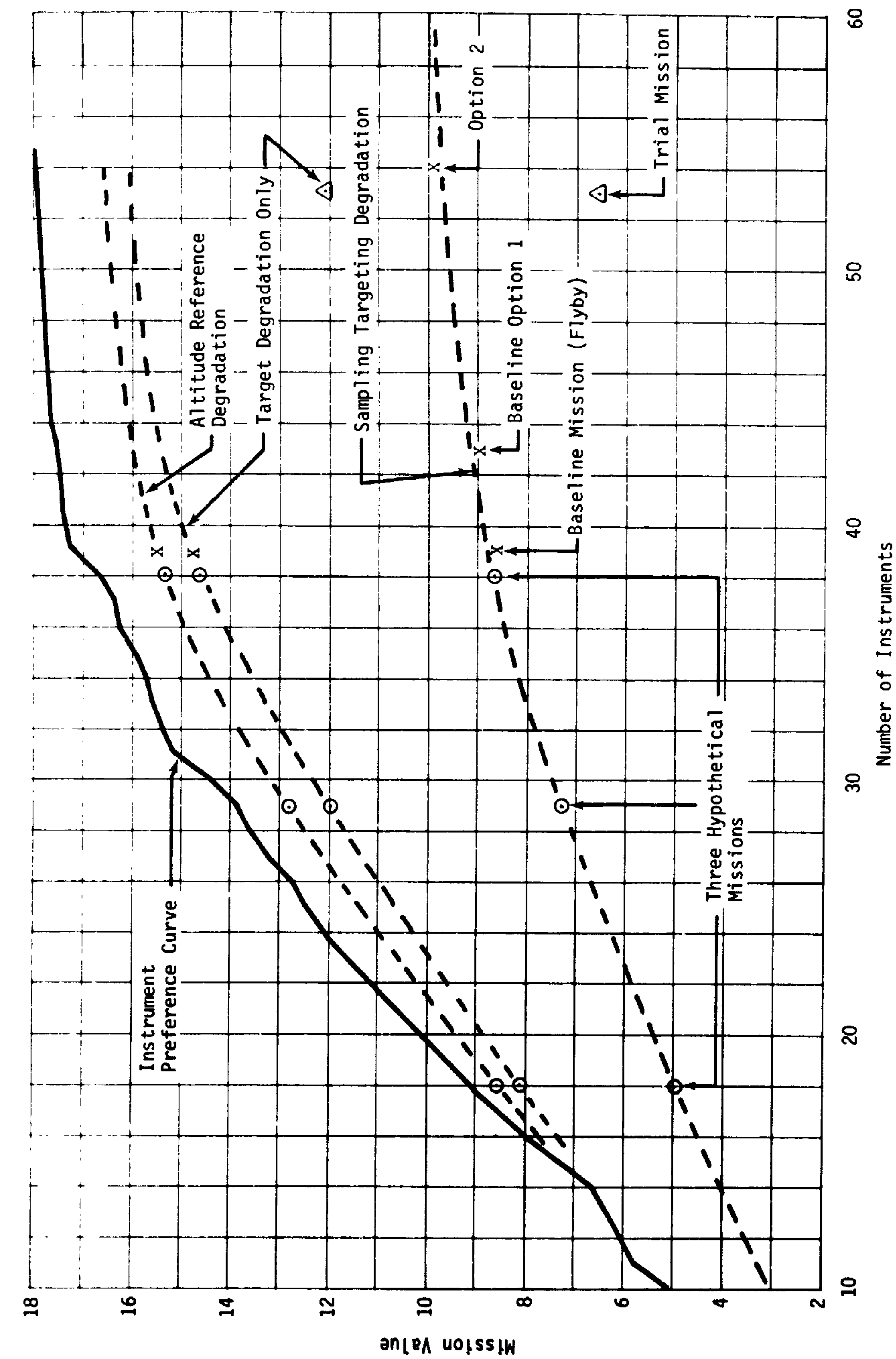


Fig. 3 Mission Value vs Number of Instruments for Optimum Missions

An obvious advantage of a mission configuration scoring well in higher priority observables can be seen over a configuration scoring well in lower priorities and having similar total mission values.

a. Comparison of the Baseline Mission Options - Figure 4 plots the science value achieved for each of the 22 science observables, arranged according to the priority of importance mentioned above. It is apparent that two of the questions, No. 5 and No. 7, dealing with cloud structure at high altitudes, have low performance capability. This low capability was due to the high altitude required for the measurements of the cloud particle composition, number, density, and size, combined with the rather slow acquisition and processing time required for the six instruments used to observe these parameters.

A second observation to be drawn from Fig. 4 is the effect produced by the two options considered for the baseline. Option 1 produced an increase in mission value by providing an answer to question 19. This question relates to the general circulation pattern of the Venus winds and requires a balloon for tracking purposes. Option 2 provides a greater total increase over the baseline configuration by increasing the value achieved for 11 of the 22 questions. A third incremental increase in total value is possible for the baseline by the use of a flyby spacecraft. This addition is due to the superior altitude reference provided by the large probe for the upper atmospheric instruments.

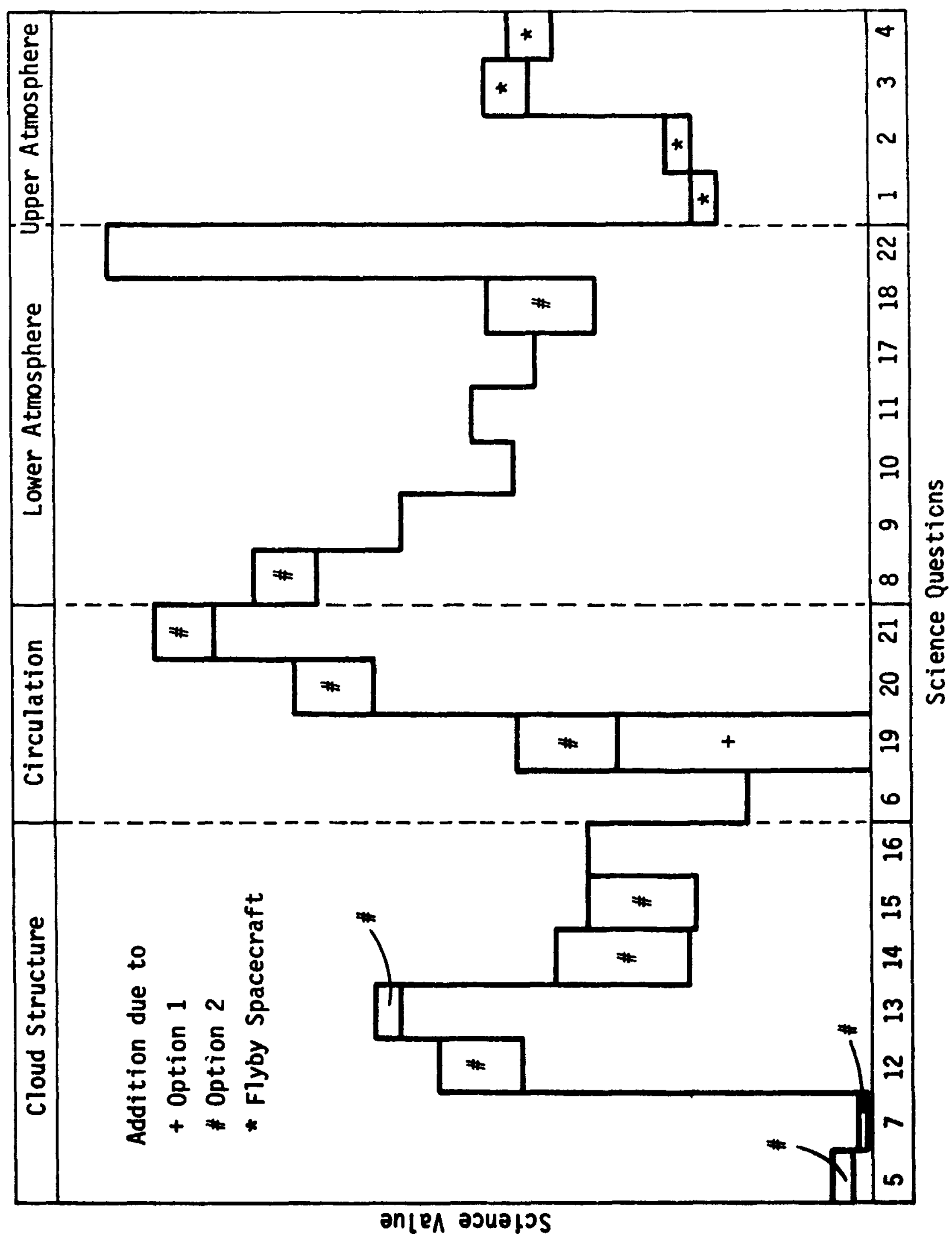


Fig. 4 Mission Effectiveness Evaluation - Effect of Options

b. Comparison of Baseline Mission to the Trial Mission - Figure 5 plots the value achieved per question for the baseline mission (solid line) along with similar data for the trial mission (cross hatched). It can be seen that the trial mission value is not as high as the baseline mission value; actually only 75%. This occurs even though the trial mission has twice as many probes and 30% more instruments. This great improvement is due to the knowledge gained from the use of the evaluation model, which allowed more valid choices to be made in the selection of instruments, probes, and target sites for the baseline mission.

D. BASELINE MISSION

1. Mission Criteria

The system and subsystem design criteria was derived from the original 18 scientific questions contained in the statement of work.* The science questions were converted into 22 "observables" which could be satisfied using data from the available instruments. See Appendix B-1 (Vol III) for the detailed list of science questions, and Table 1 for the observables. All observables were related to an instrument or group of instruments required, and to target sites and altitudes necessary to provide answers. As the instruments required at each site were tabulated the basis for mission identification was formed. The mission criteria document was then revised to reflect the configurations and operating modes required to support those instruments. The criteria document is the primary tool to convey the science objectives in terms of engineering requirements to all subsystem design groups. The criteria includes all ground rules and constraints imposed by the study.

*JPL Statement of Work. JPL Contract 952534. (Appendix A)

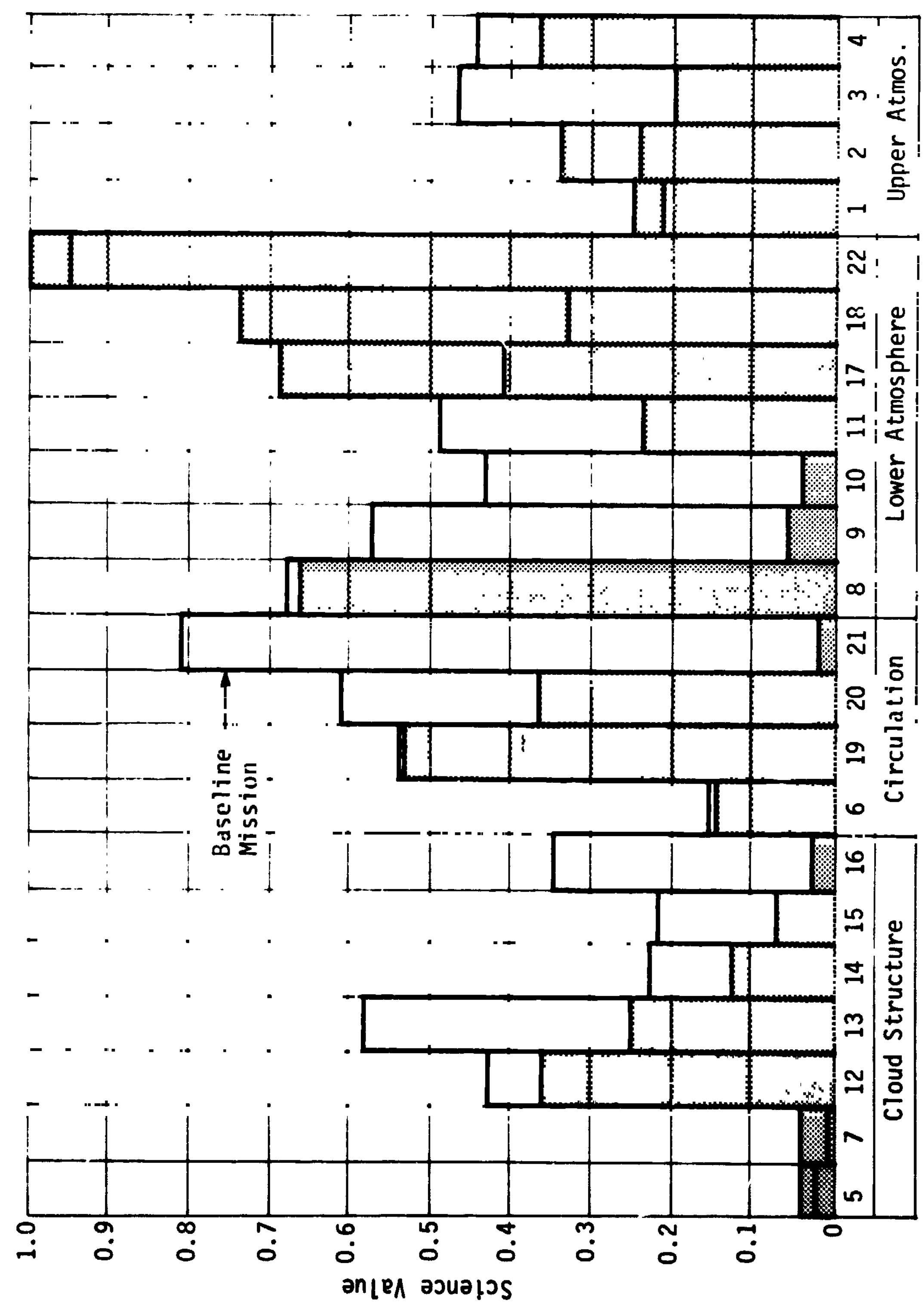


Fig. 5 Comparison of Trial and Baseline Missions

2. Baseline Mission Instruments and Sites

Table 3 identifies the probe types selected for each target zone and the instruments carried by each probe.

3. Baseline Mission Configurations

a. Entry Probe Description

1) Large Descent Probe - The large probe entry system includes the terminal descent capsule, capsule decelerator system, the deflection propulsion system, the spin-up/despin systems, and the entry aeroshell. The total system with characteristic design parameters and configuration data is shown in Fig. 6.

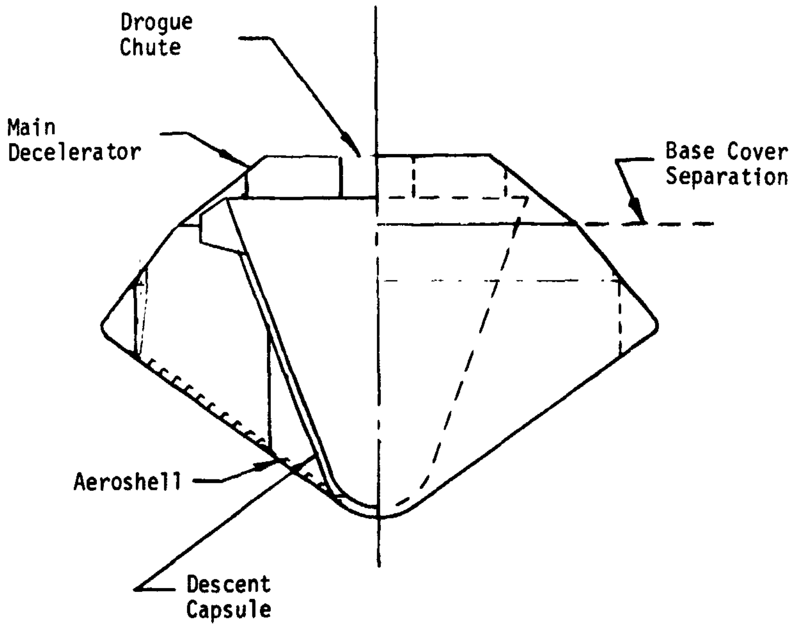
The terminal descent capsule is an aerodynamically stable sphere/cone body. The cone/half angle of 21° and a base diameter of 42.0 in. result in a ballistic coefficient of 2.0 slugs/ft^2 after parachute release. Figure 7 defines the construction and internal equipment arrangement.

The structural/thermal concept for the capsule equipment canister is a double-walled vessel. The outer canister is a pressure sustaining hermetically sealed ring-stiffened titanium shell with a quartz glass nose cap to provide an RF transparent window. The inner canister, supported from the outer by six slender straps is a hermetically sealed pressure canister. The annular space between the canisters is evacuated and lined with multilayered insulation. The equipment is mounted within the inner canister on beryllium support structure. Phase change material is interspersed adjacent to equipment items as required to absorb the heat emitted by electronic equipment and that passing through the insulation layer.

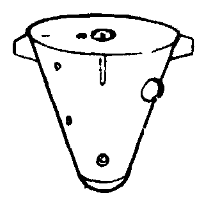
Table 3 Baseline Mission Probes/Instruments/Sites

No.	Type	Target Zone
Probe No. 1	Large Ballistic Instruments: Accelerometer Pressure Temperature Mass Spectrometer Thermal Radiometer Solar Radiometer Nephelometer Cloud Particle Number, Density, and Size Cloud Composition Evaporator/Condensimeter Altitude and Drift Radar Transponder Ion Mass Spectrometer* High Altitude Mass Spectrometer* Electron Density and TEmperature* UV Photometer*	Subsolar
Probe No. 2	Small Ballistic Instruments: Accelerometer Pressure Temperature Mass Spectrometer Thermal Radiometer Nephelometer Evaporator/Condensimeter Transponder Impact Indicator	Antisolar
Probe No. 3	Small Ballistic Instruments: Accelerometer Pressure Temperature Mass Spectrometer Solar Radiometer Nephelometer Evaporator/Condensimeter Transponder Impact Indicator	South Pole
Probe No. 4	High Cloud Instruments: Accelerometer Pressure Temperature Solar Radiometer Cloud Particle Number, Density, and Size Cloud Composition Transponder	South Pole

*These instruments are located on capsule adapter for impacting mission.



Entry Vehicle



Descent Capsule

Entry Vehicle	
Ballistic Coefficient (slugs/ft^2)	0.37
Diameter (ft)	6.25
Cone Half Angle (deg)	55.0
Weight (lb)	498.0
Decelerator (Subsonic Parachute)	
Ballistic Coefficient (slugs/ft^2)	0.035
Diameter (ft)	25.0
Descent Capsule	
Base Diameter (in.)	42.0
Cone Half Angle (deg)	21.0
Descent Time (hr)	2.18
Science Weight (lb)	73.
Bit Rate (bps)	120/60
Total Weight (lb)	275.

Fig. 6 Large Ballistic Descent Probe

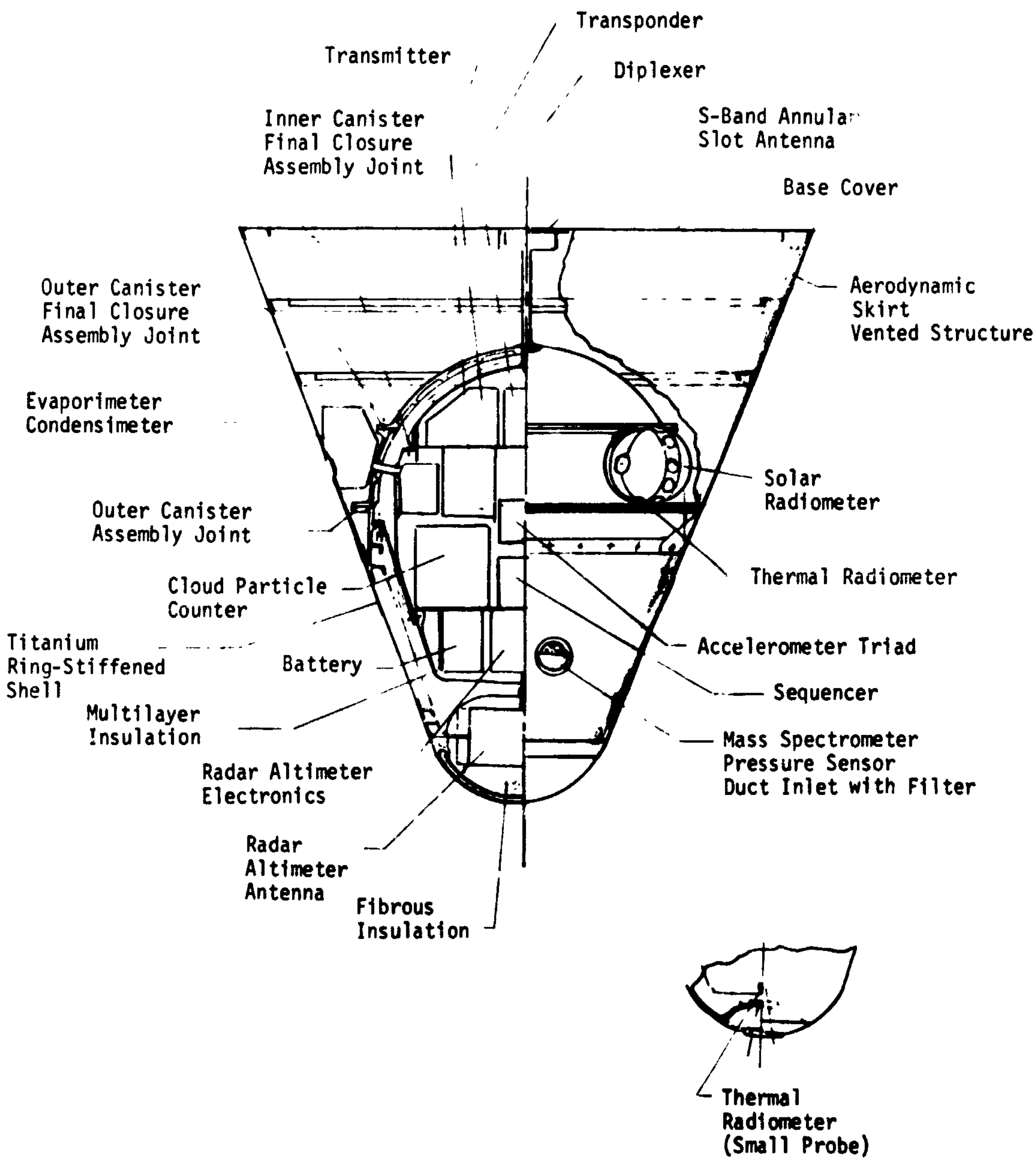


Fig. 7 Capsule Internal Arrangement

The entry aeroshell is a ring-stiffened monocoque aluminum shell frontal cone body covered with carbon phenolic ablator. The base cover is ring-stiffened with major rings at the separation plane to provide a rigid interface mounting. The base cover is coated with a lightweight elastomeric silicone ablator.

The descent capsule decelerator consists of a 25-ft-diameter subsonic parachute packaged in an annular cavity between the aeroshell base cover and the descent capsule base. It stages the descent capsule out of the aeroshell and controls its descent velocity.

Probe ejection from the spacecraft is accomplished by an eight-spring system. Spinup and deflection is provided by solid rocket motors.

The large probe science instruments are identified in Table 3.

The large probe uses a 20 W transmitter, which allows an initial postentry bit rate of 120 bps. This is switched to 60 bps in the lower atmosphere to compensate for increasing atmospheric losses and lower bit rate requirements due to decreased descent velocity. Two-way Doppler is provided on all descent probes. High-altitude science is added to the large probe in the flyby spacecraft option, which requires preentry communication at 180 bps. Because the communications look angle is markedly different in the preentry and postentry modes, a two-beam antenna system must be used on the large probe for the flyby spacecraft option. Total weight of the electronics and power system, including batteries, is 54.8 lb for the impacting spacecraft option and 58.4 lb for the flyby spacecraft option.

A total large probe weight summary is shown in Table 4 for the impacting spacecraft mission mode. This total will be increased by 28.6 lb for the flyby spacecraft mission mode when high altitude science instruments are located in the large probe.

2) Small Ballistic Descent Probe - The small probe entry system includes the terminal descent capsule, its decelerator system, the deflection propulsion, the spinup/despin systems, and the entry aeroshell. The complete system with characteristic parameters, size, and weight data is shown in Fig. 8. A total system weight summary is shown in Table 5.

The terminal descent capsule is an aerodynamically stable sphere/cone body. The cone/half angle of 21° and a base diameter of 29.0 in. result in a subsonic ballistic coefficient of 2.0.

The aeroshell design and the structural/thermal design of the capsule equipment canister is similar to the large descent probe described earlier.

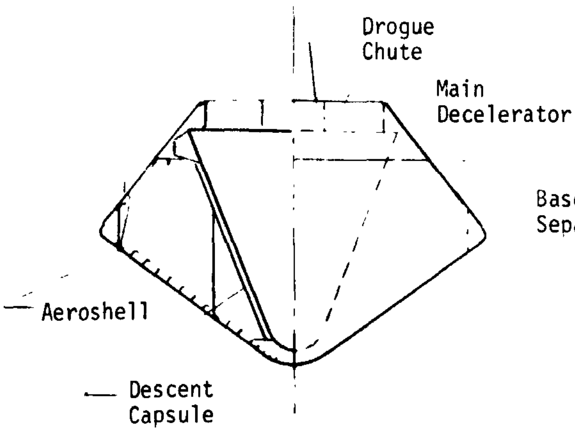
The small probe uses a 15 W transmitter. Initial bit rate is 70 bps, switched to 35 bps in the lower atmosphere. Total electronics and power system weight is 40.1 lb.

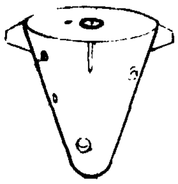
Two small descent capsule configurations are required for the baseline mission. They differ only in science instruments (the antisolar probe carries a thermal radiometer in place of the solar radiometer), however, their electronic equipment and total system weights are the same. Figure 7 shows typical canister construction and general design features for common science installations for all descent capsules.

Table 4 Large Ballistic Probe Weight Summary (Impacting Spacecraft Mode)

System	Weight (lb)	
Descent Capsule		(274.5)
Science	69.5	
Electronics	54.8	
Pressure Vessel	87.0	
Internal Structural Shell	18.0	
Internal Equipment Support and Science Integration	12.0	
Aerodynamic Skirt and Fins	12.0	
RF Nose Cap Window	4.0	
Internal Insulation	7.9	
Phase Change Material	6.3	
Antenna and Umbilicals	3.0	
Decelerator System		(21.7)
Main Parachute	16.7	
Drogue and Chute Cans	5.0	
Aeroshell		(196.0)
Aeroshell Structure Weight	106.0	
Heatshield		
Forward Cone	71.0	
Base	19.0	
Separation Hardware		(2.0)
Spinup/Despin (Fixed)		(4.0)
Entry Weight		498.2
Spin/Despin/Separation (Spent)		9.0
Biocanister/Adapter		55.0
ΔV Propulsion		7.0*
TOTAL SYSTEM		569.2†
*18 lb for flyby mode.		

†608.8 lb for flyby mode, (includes 28.6 lb for upper atmosphere instruments and electronics).





Descent
Capsule

<u>Entry Vehicle</u>	
Ballistic Coefficient (slug/ft^2)	0.40
Diameter (ft)	4.33
Cone Half Angle (deg)	55
Weight (lb)	253
<u>Decelerator</u> (Subsonic Parachute)	
Ballistic Coefficient (slugs/ft^2)	0.015
Diameter (ft)	30
<u>Descent Capsule</u>	
Base Diameter (in.)	29.0
Cone Half Angle (deg)	21.0
Descent Time (hr)	1.75
Science Weight (lb)	26.5
Bit Rate (bps)	70/35
Total Weight (lb)	132

Fig. 8 Small Ballistic Descent Probe

Table 5 Small Ballistic Probe Weight Summary (Impacting Spacecraft Mode)

System	Weight (lb)	
Descent Capsule		(131.9)
Science	26.5*	
Electronics	35.9	
Pressure Vessel	38.6	
Internal Shell and Mounting Structure	15.6	
Science Integration	2.5	
Aerodynamic Skirt	6.0	
Internal Insulation	2.3	
Phase Change Material	2.5	
Antenna and Umbilicals	2.0	
Decelerator System		(21.2)
Main Parachute	16.7	
Drogue and Chute Cans	4.5	
Aeroshell (4.33 ft diameter, 55° Half Angle)		(93.0)
Aeroshell Structure Weight	43.0	
Heatshield		
Forward Cone	40.0	
Base	10.0	
Separation Hardware		(2.0)
Spinup/Despin (fixed)		(4.0)
Entry Weight		252.1
Spin/Despin/Separation (Spent)		6.0
Biocanister		35.0
ΔV Propulsion		11.0†
Total System		304.1

*Includes transponder.

†16 lb for flyby mode.

3) <u>High-Cloud Probe</u> - The high-cloud probe entry system includes the equipment canister, its decelerator system, the deflection propulsion, the spinup/despin systems, and the entry aeroshell. The entry vehicle, the instrumentation canister, and their characteristic parameters, size and weight data are shown in Fig. 9. The total system weight summary is shown in Table 6.

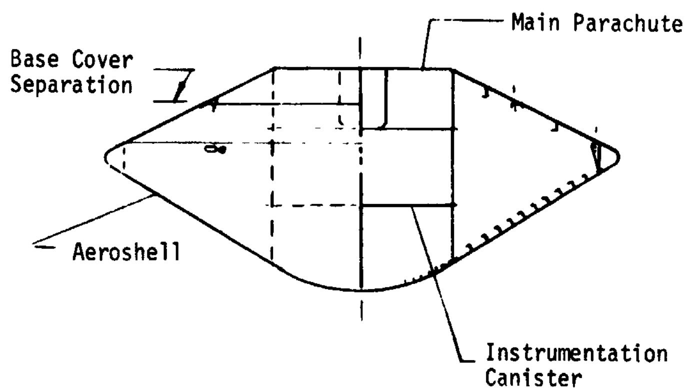
The science instrumentation and its electronics are housed in a vented cylindrical canister having a diameter of 24.0 inches and a depth of 10.0 inches. Since the high cloud probe need not survive below the 6100 km radius altitude, no provisions for protection against the extreme pressure and thermal environment below that level is included. This allows for lightweight design and enables the low ballistic coefficient desired to be achieved.

The canister structure is a fabricated aluminum cylindrical shell with angle stiffeners. The equipment is mounted to a single aluminum sandwich platform.

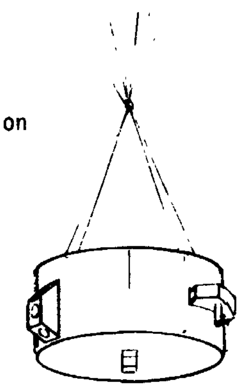
The entry aeroshell is a ring-stiffened monocoque aluminum shell frontal cone body covered with ESA 5500 abaltor. A fabricated ring frame at the major diameter supports the cone for the entry pressure loads. The base cover is a ring stiffened shell with major rings at its separation interface. The base cover heat shielding is the ESA-5500 ablator.

The instrumentation canister deployment and decelerator chute is packaged in an annular cavity between the aeroshell base cover and the canister.

The high-cloud probe is not required to operate in the lower atmosphere, so no margin in transitter power is allowed for atmospheric losses and the bit rate is not switched from its initial value of 50 bps. An 8 W transmitter is used. Total electronics and power system weight is 34.4 lb.



Entry Vehicle



<u>Entry Vehicle</u>	
Ballistic Coefficient (slug/ft^2)	0.2
Diameter (ft)	5.75
Weight (lb)	255
<u>Decelerator (Subsonic Parachute)</u>	
Ballistic Coefficient (slug/ft^2)	0.005
Diameter (ft)	45
<u>Canister</u>	
Science Weight (lb)	39.5
Bit Rate (bps)	50
Operating Time (hr)	1.35
Total Weight (lb)	85

Fig. 9 High-Cloud Probe Configuration

Table 6 High-Cloud Probe Weight Summary
(Impacting Spacecraft Mode)

System	Weight (lb)	
Instrumentation Canister		(85.0)
Science	39.5	
Electronics	30.5	
Structure and Mechanics	15.0	
Decelerator System		(51.0)
Main Chute	44.0	
Drogue and Canister	7.0	
Aeroshell		(113.0)
Aeroshell Structure Weight	68.0	
Heatshield		
Forward Cone	30.0	
Base	15.0	
Separation Hardware		(2.0)
Spinup/Despin (Fixed)		(4.0)
Entry Weight		255.0
Spin/Despin/Separation (Spent)		6.0
ΔV Propulsion		9.0*
Biocanister/Adapter		46.0
Total System		316.0

*16 lb for flyby mode.

b. Planetary Vehicle - The Planetary Vehicle is the combination of spacecraft, entry probes, biocanisters, and adapters placed on the interplanetary transfer trajectory. The general arrangement of the Planetary Vehicle inside the payload fairing is shown in Fig. 10.

1) Spacecraft Configuration - The spacecraft designated as the basis of this study is configuration 20a with modifications as required for the multiple probe mission. The high-gain and low-gain antennas must be relocated as shown in Fig. 11 to be compatible with 1975 Type II mission geometry. A second low-gain antenna has been added to assure access to the command system during all separation maneuvers. The structural members will be unchanged since no new loads will be applied to it. Additional capacity in the ACS will be provided outside the spacecraft body by enlarging the tanks on the topside by approximately 15%. The midcourse thruster will be relocated so that its vector is through the Planetary Vehicle center of gravity. The thrust levels of the ACS will be increased to account for the increased system inertia.

Raw solar electric power will be supplied from the spacecraft to the capsule adapter for battery charging during interplanetary cruise. The data interface between spacecraft and adapter will include status monitor signals from the entry capsules, and the high altitude science data on the impacting mission.

The spacecraft command link will also interface the capsule adapter to initiate warmup and capsule separation. Additional capacity in the central computer and sequencer (CC&S) must be provided to accommodate the attitude maneuver sequence for the capsule separation.

See Table 7 for Planetary Vehicle weight summaries.

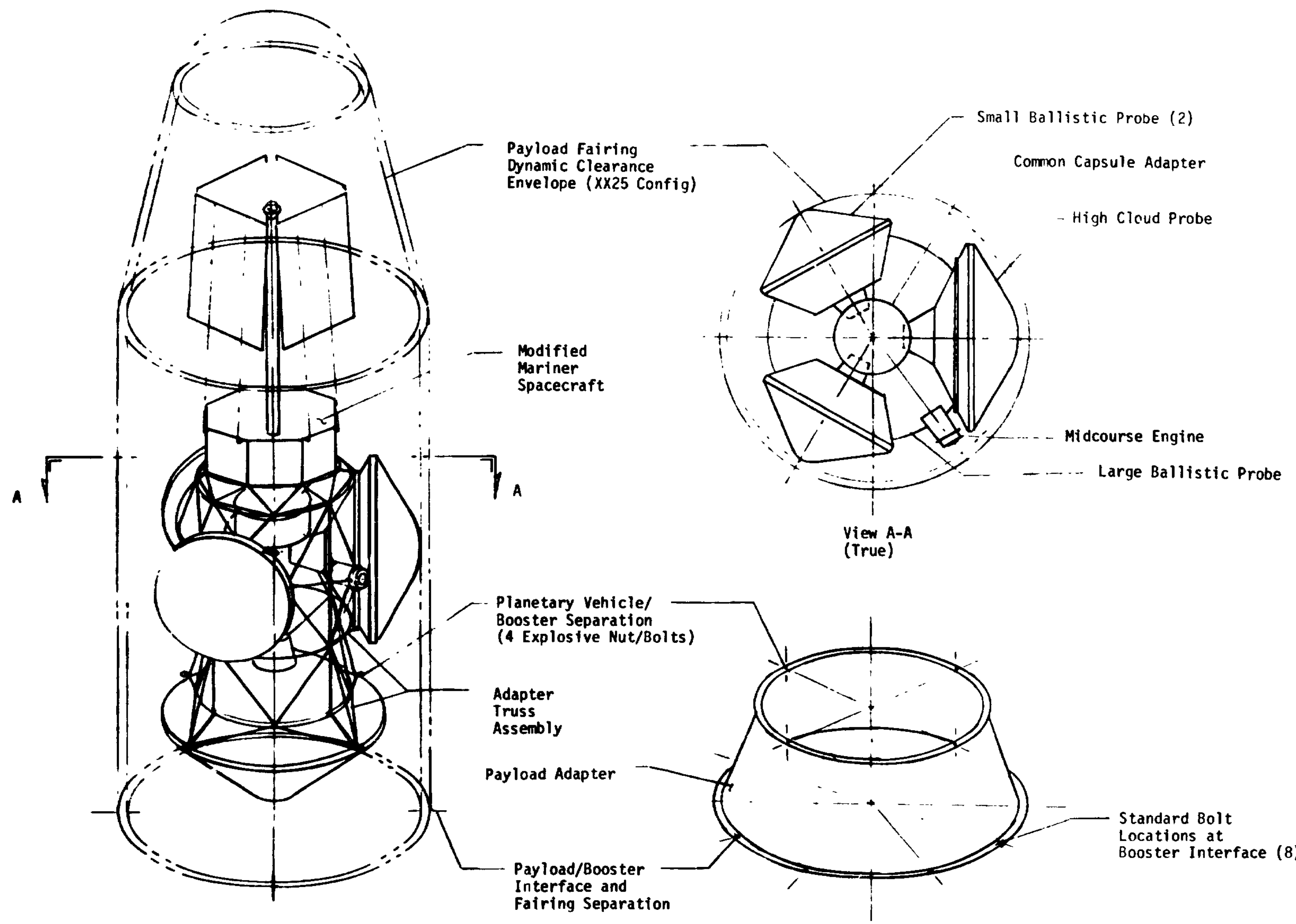


Fig. 10 Baseline Planetary Vehicle General Arrangement and Booster Integration

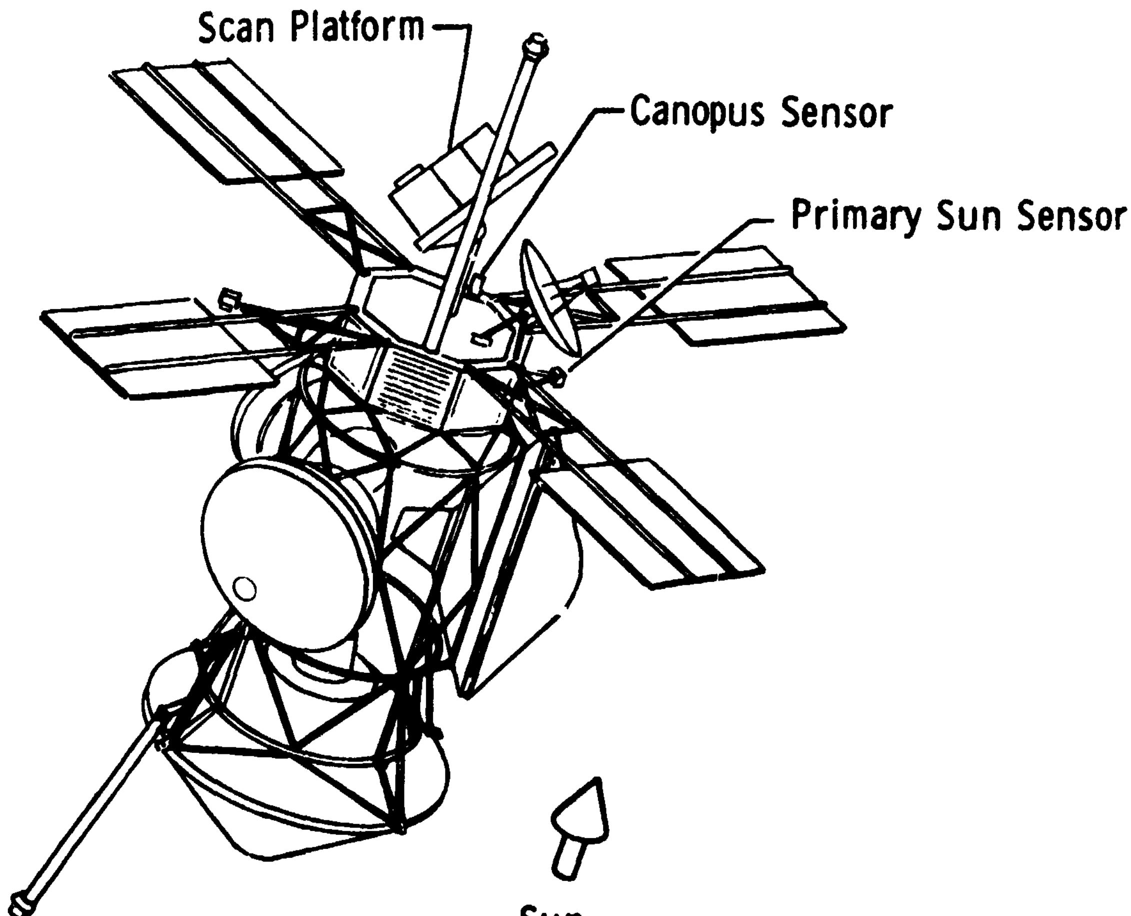


Fig. 11 Baseline Mission, Planetary Vehicle

Item	Impacting Mode	Flyby Mode
	Weight (lb)	
Probes Separated (4)	1325.	1381.6
Biocanisters/Adapters	171.	171.0
High Altitude Science and Electronics	28.6	0*
Adapter Truss Assembly Umbilicals and Cabling	292.	292.0
Payload Adapter	98.	98.0
Spacecraft	824.	819.5
	2738.6	2762.1
Contingency	380.	386.0
	3118.6	3148.1

*Included in probe weights.

2) Capsule Adapter - The capsule adapter is an assembly used to marry the multiple probes to the spacecraft with minimal interface problems. It consists of capsule support structures, separation equipment, and electronic service equipment. High altitude science instruments, midcourse propellant, batteries, and cabling are located on the adapter. The adapter serves as a single interface for all capsules with the spacecraft, for data, power, commands, and discrete signals. It also has a separation sequencer so that the common functions required for each capsule can be accomplished by the adapter rather than by equipment duplicated for each capsule.

3) Biological Canisters - Biological canisters are required for only the individual entry capsules for the flyby mission mode, and for the capsules as well as the entire planetary vehicle for the direct impacting mission mode.

Entry Capsule Biocanisters - Since three basic probe types and operating modes are used in the baseline mission, it is apparent that three separate paths should be pursued to produce the most compatible sterilization protection approach for each.

The first entry capsule approach considers the probes that pass rapidly through the altitude zone that is conducive to life forms. This includes the large and small probes. These probes must be sterilized externally, including heat shield, decelerators, ordnance items, and all exposed surfaces. The equipment placed inside the pressure vessel need not be sterilized because the probability of failure of the structural pressure vessel can be made sufficiently low to satisfy mission requirements.

The high-cloud probe must follow a second plan because it will not be built with the equipment packaged in a high strength, sealed, pressure vessel. The internal parts of the system must be sterilized because a structural breakup could occur while the probe is still in a moderate temperature zone in the atmosphere.

The balloon probes present the third operational mode. They will operate at a pressure level that is not difficult to handle; however they will remain in an atmosphere conducive to life for extended periods. These capsule, parachutes, balloons, and inflation systems will be heat sterilized.

The individual entry probe biocanisters will be constructed of thin gage aluminum designed to separate the front portion to allow probe ejection. The aft portion will remain on the capsule adapter truss.

Planetary Vehicle Biocanisters - The flyby mission mode does not require a Planetary Vehicle biocanister because all entry articles will be sterilized and contained in individual sealed biological canisters. Before the Planetary Vehicle is reoriented for capsule separation, the biocanisters will be separated so that an inadvertent entry into the planet's atmosphere will not occur.

The direct impacting spacecraft mission presents a requirement considerably different from the above approach. The study constraints require that the portion of the atmosphere conducive to life not be contaminated. Therefore, the capsules, capsule adapter, and spacecraft must all be sterilized and protected from contamination until out of the earth's atmosphere.

The method selected for the baseline mission configuration will be to assemble sterilized capsules, spacecraft, and capsule adapter under clean room conditions. This payload may then be attached to the launch vehicle above a bilogically secure barrier. A lightweight container will enclose all entry items inside the payload fairing. Ethylene oxide will then be introduced into the container for an appropriate time to resterilize the exterior of the items which were exposed to contamination after sterilization. This container will remain intact until the Launch Vehicle is out of the earth's atmosphere and will remain with the Launch Vehicle final stage. The biocanisters will then be used primarily to provide thermal control surfaces, because they will be sterilized inside and out. They will remain with the entry capsules until just before capsule separation, however they need not be deflected to a nonimpacting trajectory.

4) Planetary Vehicle Interfaces for the Baseline Mission - Interfaces between the Mariner Spacecraft (AVCO configuration 20a) and the entry capsule systems will be accommodated by a Common Capsule Adapter which will include provisions for the following functions:

Mounting the entry capsules, capsule support equipment, and the spacecraft;

Providing functional capability for assembly, prelaunch checkout, and inflight support of capsule systems; initiation of capsule sequencers, and sequencing of capsule release;

Providing an overall biocanister if an impacting spacecraft mission is used;

Interfacing the Planetary Vehicle with the Launch Vehicle and with the Payload Fairing.

Assembly - The Common Capsule Adapter will provide the capability for determining mass properties in all configurations in which the Planetary Vehicle will exist during the mission.

Prelaunch Checkout - The Common Capsule Adapter will provide the capability for prelaunch checkout of capsule systems, separately from the spacecraft, and verification of the interfaces between the spacecraft and the Common Capsule Adapter. Spacecraft checkout requirements will be accommodated by cabling routing to accessible locations.

Launch to Celestial Acquisition - The XX25 payload fairing will be separated 280 sec into the flight. Planetary Vehicle separation from the Launch Vehicle (Titan IIIC transtage) will be followed by deployment of the solar panels and sun acquisition. At this time the spacecraft will begin supplying approximately 3 W of power for battery trickle charging and operation of capsule status monitoring equipment. Canopus acquisition will complete the celestial references for interplanetary cruise.

Interplanetary Cruise and Midcourse Correction - The spacecraft will accept digital data streams compatible with spacecraft formats from the Common Capsule Adapter, the data being indicative of capsule systems status. The spacecraft attitude control system will be augmented to compensate for the larger moments of inertia in maintaining the attitude within the deadband of ±4 mrad. The midcourse correction maneuver will require relocation of the spacecraft thruster assembly to align the thrust vector through the cg of the Planetary Vehicle. The deployable low gain antenna of AVCO configuration 20a will require relocation in the +Z (sun end) direction to the structure of the Common Capsule Adapter. Methods of meeting these requirements are subject to trade studies that are influenced by the choice of flyby or impacting spacecraft missions.

Capsule Separation - At entry - 294:45:00 (impacting spacecraft) the spacecraft gyros will be turned on and all capsule biocanister covers will be separated. (The covers will be sterile so that planetary quarantine requirements will not be violated). Sixty eight minutes later, the spacecraft will perform a pitch maneuver to achieve attitude orientation for separation of the small ballistic probe to the South Pole. At the completion of the maneuver a signal from the spacecraft will start the sequencer of the Common Capsule Adapter. The sequencer will initiate the capsule, control all separation functions, and signal to the spacecraft that release has occurred.

Pitch and roll maneuvers and separation events will separate the remining capsules, followed by return of the spacecraft to celestial reference. The separation sequence that has been developed indicates that celestial reacquisition can be attained at E-292:30:07. Impacting spacecraft science will be activated 5 planet radii from the surface at E-01:30:00 for collection of data until destruction during entry. The Common Capsule Adapter will mount the instruments, process the data, and provide data streams to the spacecraft for transmission to earth.

4. Baseline Mission Trajectory Summary

The baseline mission utilizes a Type II trajectory that has an October 31, 1975 arrival. A 20-day launch period is available between May 15, 1975 and June 4, 1975. The maximum C_3 value for this mission is 6.8 km^2/sec^2 and the maximum V_{HE} is 3.68 km/sec. These conditions yield a 4000-lb payload capability for the Titan IIIC. Launch window and coast time constraints do not restrict this mission. The communications range at arrival is 95×10^6 km and the maximum mission time is 169 days. The arrival geometry and target locations are shown in Fig. 12: (1) subsolar, (2) South Pole, (3) antisolar, and (4) light side morning terminator.

The deflection and entry parameters are defined in Table 8 for impacting spacecraft missions. The impacting spacecraft is targeted to the subsolar point and has the same entry characteristics as the large probe. The periapsis radius is 2800 km. The flyby spacecraft has a periapsis radius of 12,600 km; other entry parameters are essentially the same as in the impacting case. The deflection velocity increases by 40 m/sec in each case and the entry angle of attack is reduced by up to 15 deg. The entry sequence is shown in Fig. 13 for both impacting and flyby spacecraft.

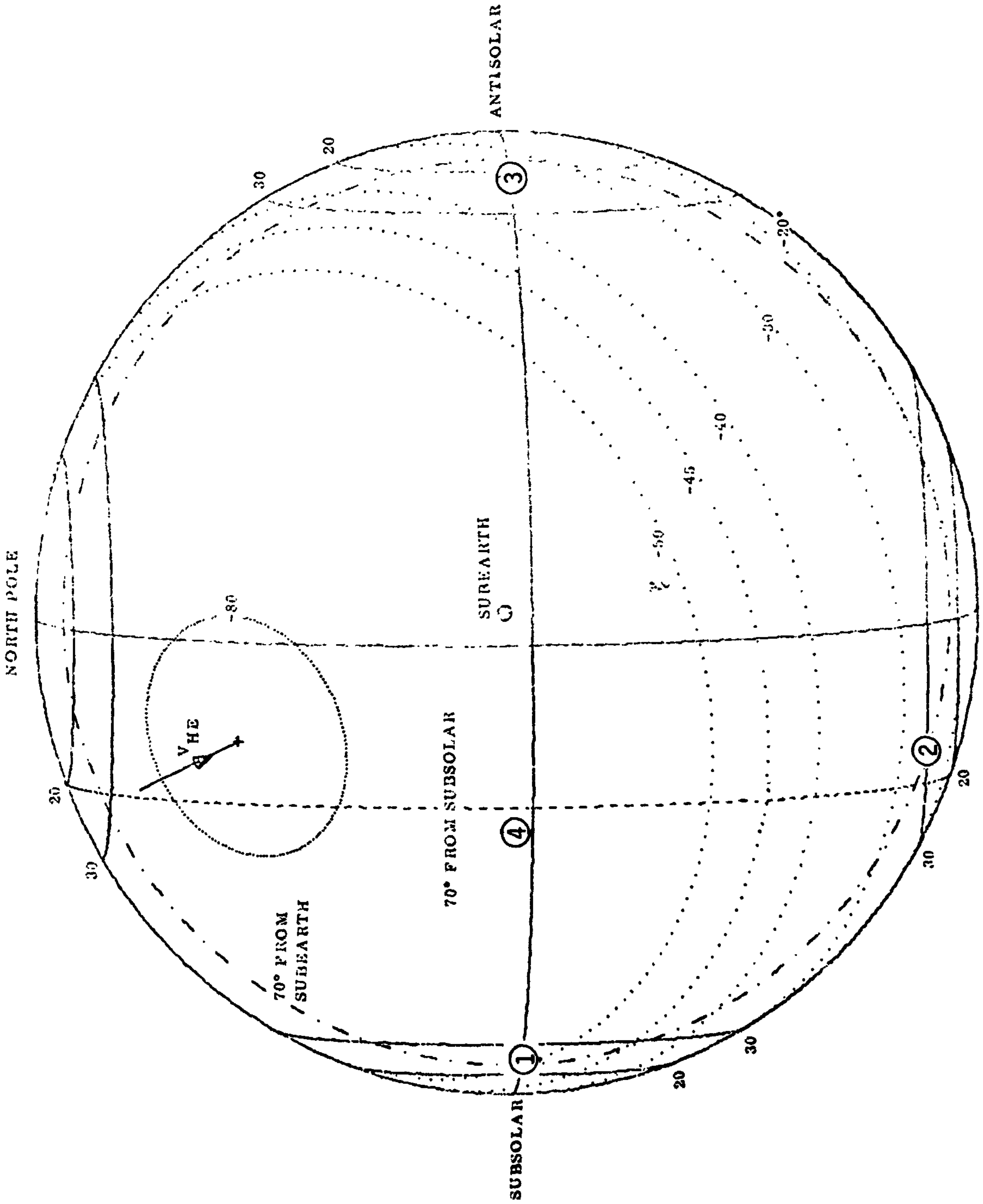


Fig. 12 Venus as Seen from Earth on October 31, 1975

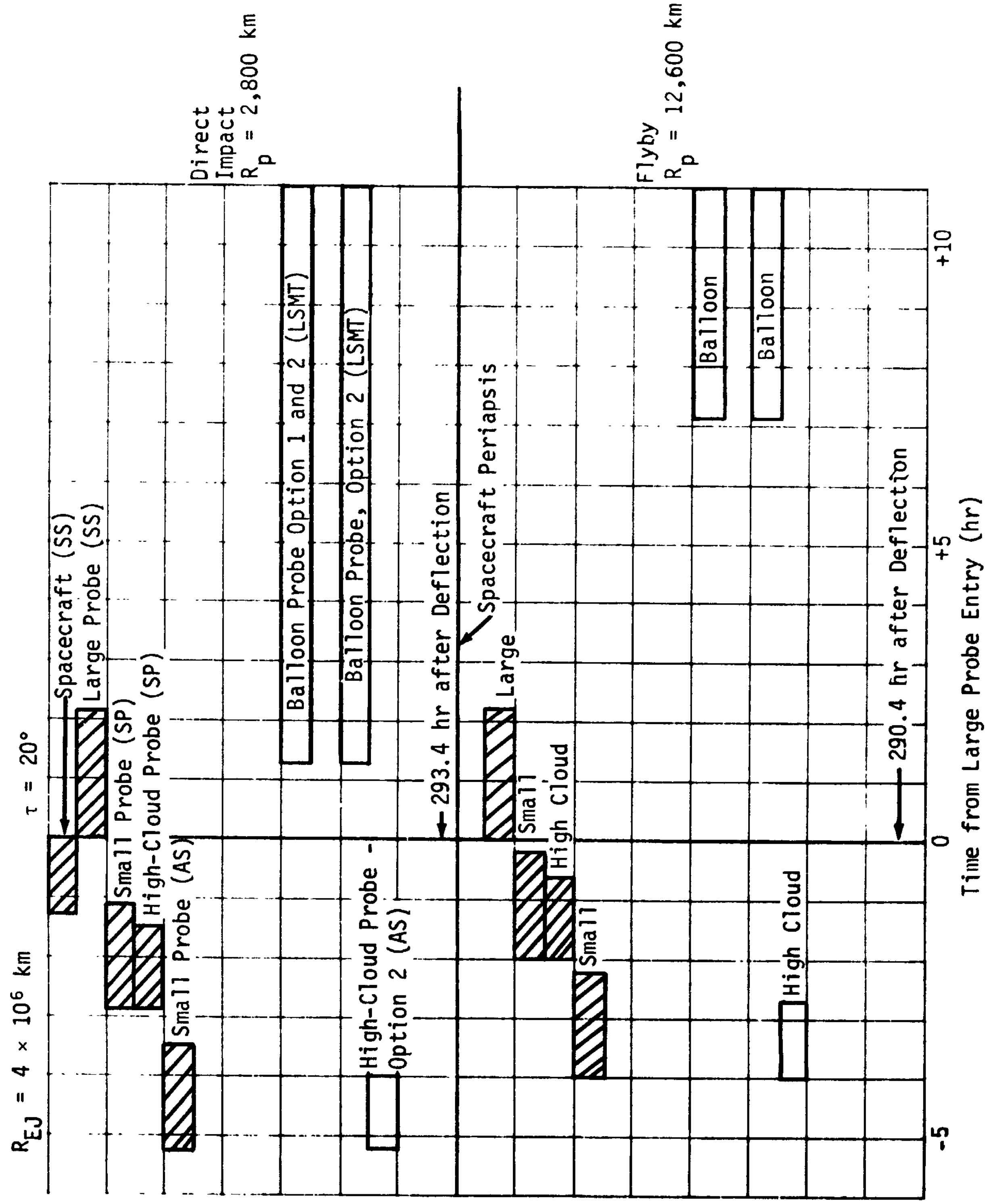


Fig. 13 Mission Operating Sequence

Table 8 Baseline Deflection and Entry Parameters

Entry Altitude	248.4 km (815,000 ft)			
Entry Velocity	10.78 km/sec (35,367 fps)			
Deflection Radius	4×10^6 km			
Deflection Angle	20° (160° for Balloons)			
Targets	Subsolar	Polar	Antisolar	LSMT
Latitude (deg)	-1.09	-62.02	0.42	0.76
Longitude (deg)	24.38	83.15	157.75	69.86
Entry Path Angle, γ_E (deg)	-50	-25	-35	-65
Entry Angle of Attach, α_E (deg)	21.2	50.5	46.5	155.4
Deflection Velocity (msec)	0 to 5	45	70	22
Time from Deflection to Entry (hr)	293.4	290.6	289.1	294.7

5. Baseline Mission Operation

Mission operation begins with assembly of sterilized entry capsule systems, spacecraft, and capsule adapter on the Launch Vehicle at the launch pad. Subsequent to terminal sterilization (for the impacting mission only) and preflight checkout, the launch is initiated. The launch procedures will be standard for the Titan IIIC vehicle and Mariner spacecraft, however, the entry capsule systems will be dormant. Payload fairing and Planetary Vehicle separation will occur as normal Launch Vehicle functions. Midcourse maneuvers will be performed in the normal Mariner mode of operation. During interplanetary cruise raw power from spacecraft solar cells will be supplied to capsule batteries, and capsule status monitoring will be transmitted by the Mariner telemetry system.

Approximately 300 hr before spacecraft entry the spacecraft ACS and entry probe system are prepared for separation, initiated by earth command. The Mariner ACS will reorient the Planetary Vehicle to the proper attitude for each probe deflection velocity impulse and the probes are separated. Each entry probe is spun about its longitudinal axis to provide attitude stabilization, and after a 20 minute nutation damping period, the deflection velocity propulsion system is fired. Subsequent to shutdown, the deflection propulsion system is jettisoned, and the entry capsule systems are powered down for the coast to the planet.

Twenty minutes before entry a timer powers up the entry capsule systems and a despin system is initiated.

The entry capsules are protected during entry heating by the heat shield, and after the heating pulse and high deceleration period, a parachute is deployed to separate the terminal descent capsule from the aeroshell. This operation also initiates science instrument deployment and data transmission. See Chapter V of Volume II for detailed sequence of events. The probe entry and activity sequence is adjusted to provide for a maximum of two probes transmitting simultaneously to be compatible with the deep space net. The mission terminates with surface impact for ballistic descent probes, and at an altitude of 6100 km radius for the high-cloud probe.

E. OPTIONAL MISSIONS SUMMARY

The two optional missions identified during the study are essentially two levels of increased science capability. Both consist of additional probes complementing the baseline mission. Tables 9 and 10 identify the probes/instruments/and target zones for each option. The major effect of the options is to create a new probe type, a floating balloon whose position can be monitored from earth by ranging and antenna polarization measurements. The basic purpose of balloon probes is to provide more complete data regarding atmospheric circulation.

Table 9 Mission Option 1 Description

Probe No.	Type	Target Zone
1	Same as Baseline 1	Same as Baseline
2	Same as Baseline 2	Same as Baseline
3	Same as Baseline 3	Same as Baseline
4	Same as Baseline 4	Same as Baseline
5	500 mb Float Altitude Balloon Instruments: Pressure Temperature Solar Radiometer Transponder	Light Side Morning Terminator

Table 10 Mission Option 2 Description

Probe No.	Type	Target Zone
1	Same as Baseline 1	Same as Baseline
2	Same as Baseline 2	Same as Baseline
3	Same as Baseline 3	Same as Baseline
4	Same as Baseline 4	Same as Baseline
5	Same as Option 1 (Probe No. 5)	Same as Option 1
6	[illegible]0 mb Float Altitude Balloon Instruments: Same as Probe 5	Light Side Morning Terminator
7	High Cloud Instruments: Same as Baseline 4	Antisolar

The Option 2 mission uses no additional new probe types, however, a second balloon probe and another high-cloud probe are added.

This section is essentially devoted to the balloon probe configuration description since all other probes are taken directly from the baseline mission configuration. Tables 11 and 12 show Planetary Vehicle weight summaries for the optional missions.

1. Balloon Probe Configuration

The balloon probe's entry system includes the buoyant probe and its inflation hardware, the decelerator system, the deflection propulsion, the spinup/despin systems, and the entry aeroshell. The entry vehicle inboard profile, the deployed buoyant probe, and their characteristic parameters, size and weight data are shown in Figure 14. Total system weight summaries are shown in Tables 13 and 14. Two configurations of buoyant probes are defined in accordance with the ambient pressure at float altitude. These are the 50 mb and the 500 mb balloons.

The gondola canister for the 500 mb buoyant probe is a vented design, however the 50 mb probe is sealed and insulated. The balloon is clamped to a tubular adapter in the center of the gondola. An annular shell surrounding the balloon neck and adapter houses the science instrumentation and the electronics.

The gondola structure is a fabricated aluminum cylindrical shell with angle stiffeners. The equipment is mounted to a single aluminum sandwich annular platform.

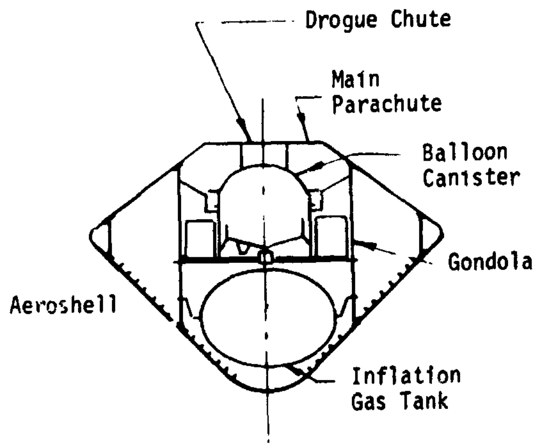
The balloon inflation gas is contained in a filament-wound tank of oblate spheroid shape mounted within a skirt shell structure below the gondola. After balloon inflation, the inflation tank and skirt section are jettisoned.

Table 11 Option 1 Planetary Vehicle Weight Summary (Impacting Spacecraft Mode)

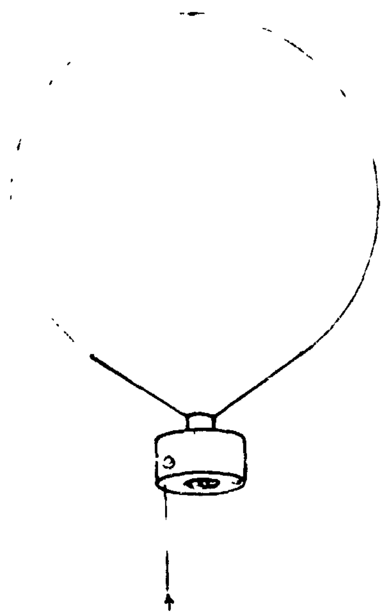
Item	Weight (lb)
Probes Separated (5)	1570
Biocanisters/Adapters	206
High Altitude Science and Electronics	28.6
Adapter Truss Assembly Umbilicals and Cabling	313
Payload Adapter	100
Spacecraft	824
	3042
Contingency	443
Total	3485

Table 12 Option 2 Planetary Vehicle Weight Summary (Impacting Spacecraft Mode)

Item	Weight (lb)
Probes Separated (7)	2247
Biocanisters/Adapters	292
High Altitude Science and Electronics	28.6
Adapter Truss Assembly Umbilicals and Cabling	492
Payload Adapter	105
Spacecraft	824
	3926
Contingency	74
	4000



Entry Vehicle



	Float Altitude	
	500 mb	50 mb
Entry Vehicle		
Ballistic Coefficient (slug/ft^2)	0.55	0.60
Diameter (ft)	4.00	4.70
Weight (lb)	234.0	395
Decelerator		
Ballistic Coefficient (slug/ft^2)	0.032	0.032
Diameter (ft)	17	23
Balloon		
Diameter (ft)	13	32
Gondola		
Science Weight (lb)	11	11
Bit Rate (bps)	25	25
Nominal Duty Cycle	7 min every 8 hr	
Minimum Life Time (days)	7	7
Total Weight (lb)	70	120

Fig. 14 Optional Mission Balloon Probes

Table 13 Balloon Probe Weight Summary (500 mb Configuration)

System	Weight (lb)	
Buoyant Probe, (Floated Weight)		(70.0)
Science	11.0	
Electronics (7-Day Lifetime, Min)	31.0	
Structure	12.0	
Inflation Hardware	2.5	
Balloon (13.0 ft dia)	10.5	
Hydrogen in Balloon	3.0	
Staged Items		(62.0)
Inflation Tanks	45.7	
Residual Hydrogen	0.3	
Structure and Separation Hardware	6.5	
Parachute	7.0	
Parachute Canister/Hardware	2.5	
Aeroshell		(90.0)
Aeroshell Structure	48.0	
Heat Shield		
Forward Cone	33.0	
Base	9.0	
Separation Hardware		(3.5)
Spinup/Despin (Fixed)		(4.5)
Drogue and Canister		(4.0)
Entry Weight		234.0
Spin/Despin/Separation (Spent)		6.0
ΔV Propulsion		5.0
Biocanister/Adapter		35.0
Total System		280.0

Table 14 Balloon Probe Weight Summary
(50 mb Configuration)

System	Weight (lb)	
Buoyant Station (Floated Weight)		(119.6)
Science	11.0	
Electronics (7-Day Lifetime)	43.6	
Structure	25.5	
Inflation Hardware	2.5	
Balloon	31.5	
Hydrogen in Balloon	5.5	
Staged Items		(107.0)
Inflation Tank	84.0	
Excess Hydrogen	0.5	
Support Structure/Hardware	7.5	
Parachute	12.0	
Parachute Canister/Hardware	3.0	
Aeroshell		(154.0)
Aeroshell Structure	76.0	
Heat Shield		
Forward Cone	62.0	
Base	16.0	
Separation Hardware		(3.0)
Spinup/Despin (Fixed)		(5.5)
Drogue and Canister		(6.0)
Entry Weight		395.1
Spin/Despin/Separation (Spent)		7.0
ΔV Propulsion		8.0
Biocanister/Adapter		45.0
Total System		455.1

The entry aeroshell is a ring-stiffened monocoque aluminum shell frontal cone body covered with ESA 5500 ablator. A fabricated ring frame at the major diameter supports the cone for the entry pressure loads. The base cover is a ring stiffened shell with major rings at its separation interface. The base cover heat shielding is also the ESA 5500 ablator.

The flotation system consists of the balloon sphere, gaseous hydrogen stored at 4500 psi in the filament wound tank, and pressure control valving and sensors. The 500 mb balloon is constructed of a laminated Kapton film gas barrier and a Nomex load-carrying fabric. The balloon has a diameter of 13 ft. The required hydrogen gas weight is 3.0 lb. The 50 mb balloon is constructed of a laminated Kapton film that provides both the gas barrier and the load-carrying structure. This balloon is 32 ft in diameter and requires 5.5 lb of hydrogen. The 50 mb balloon gondola is heavier than the 500 mb balloon because it must carry additional double wall structure, insulation, batteries, and heater to provide thermal control on the dark side of the planet.

The balloon probes' communication operations differ in many respect from the descent probes. They are contacted periodically throughout their lifetime while visible from earth. This contact, which lasts for 7 minutes each 8 hr, consists of a short period of data transmission and a position-fixing transmission consisting of a two-way ranging and an antenna polarization measurement. Solar panels are provided to supplement the probe power system while on the planet light side, and batteries are provided for a 7-day dark-side lifetime. The 50 mb balloon uses an electric heating system, requiring a heavier power system. Weights for the electronics and power systems are 31.0 lb for the 500 mb balloon and 43.6 lb for the 50 mb balloon.

2. Balloon System Operation

Operation of the balloon probes from separation from the Planetary Vehicle until parachute deployment is identical with the other probes, except that parachute deployment and balloon inflation altitude is not as critical because the balloons will return to their proper float altitude. For this reason the parachute deployment altitude and velocity will be lower to minimize parachute design loads.

No provisions are made for storage of entry data in the balloons and data transmission will be initiated at the time of balloon extraction. The remaining events will be transmitted in real time, including both engineering and science data.

The first transmission from the balloon, and also operation of earth-based ground systems, varies depending on the use of an impacting spacecraft or a flyby spacecraft. The impacting case brings the balloons into operation while data are being collected from the large ballistic probe. The DSIF is not capable of two-way ranging to the balloons unless the two-way communications with other probes is complete. Accordingly, for the initial contact only, no tracking information will be acquired from the balloons. Each balloon will use a one-way link on this initial contact only, and transmission will be limited to data only. The effect of this is that balloon science and engineering data, but no position fix, will be available for the first transmission which is automatically initiated on board. Transmissions subsequent to the first will use a two-way link. They will provide a position fix in addition to the data transmission, and will be the same as for the flyby spacecraft, which has no overlap with other probes. Transmission in this case follows the sequence outlined below:

1) Transmission from the balloon(s) will depend on the balloon receiving a carrier from the ground, except the first transmission which will be automatic. This will not require a full command system, but will require a "signal present" indicator in the balloon receiver;
2) The balloon receiver will be activated for 1 minute and if a carrier is not received, the receiver will be deactivated;
3) If a carrier is received, the balloon transmitter will be activated and will transmit as follows:
   a) ½ minute without data for ground search and lock on,
   b) 2-minute transmission of science and engineering data at 20 bps,
   c) 2½ minutes of relaying the ranging signal, without data, for ranging determination,
   d) 30 minutes of transmitter deactivation to allow conversion of earth-based antennas,
   e) 2 minutes of transmission without data for polarization determinations;
4) The balloon receiver will be activated once each hour by its internal sequencer to allow the sequence of 2) and 3) above. Mission operations procedures will determine if the transmitter is to be activated to obtain data at frequent intervals, or to remain inactive to conserve power;
5) The balloon power system with solar panels will accommodate the sequence indefinitely as long as the balloon is on the light side. If the balloon goes to the dark side, seven days of transmission, once

every 8 hr, will be possible. If the balloon goes to the dark side, and returns to the light side within seven days, indefinite operations will again be possible. This is ultimately limited by the lifetime of the balloon itself.

F. SUMMARY OF SUPPORTING ANAYSES

1. Trajectory Analysis

The interplanetary trajectory analysis used JPL-generated trajectory data for the 1975 launch opportunities for the Venus mission. The direct communication constraint on available launch and arrival dates was identified and tradeoffs examined between payload capabilities of the Titan IIIC, distance from the desired target point, impact of launch period duration, planetary surface location of V_{HE}, communications range, and other parameters. A launch period and arrival date were defined and the resulting interplanetary trajectory parameters identified for a trial mission study and for the baseline mission study.

At encounter, both impacting and flyby spacecraft paths were considered. The radius of periapsis is the measure of difference between the two cases, and its impact on deflection maneuvers, entry parameters, and targeting accuracies has been evaluated.

The deflection maneuvers were investigated to achieve the desired target sites with each probe while maintaining reasonable entry dispersions, entry angles of attack, and deflection velocity increments. Staggered entry times were investigated to satisfy a requirement for communication to a maximum of two probes simultaneously. The sequence of events for each deflection maneuver was identified and the spacecraft capabilities for achieving the proper pointing angles were evaluated. A trial mission and baseline mission were defined.

Entry parameters were evaluated to define probe criteria for deceleration to subsonic speeds above the cloud tops. Entry ballistic coefficients from 0.1 to 1.0 were evaluated at entry angles between -20° and -90°. The effect of entry velocity and atmosphere model was defined. The nominal entry velocity was about 10.8 km/sec (35,400 fps). Entry parameters were selected for both the trial mission and the baseline mission.

Descent studies were conducted to define the altitude-velocity-time profiles. These profiles supported the studies of communications, data collection and handling, and science goals. Staging techniques were evaluated and descent profiles presented for each probe in both the trial and baseline missions.

An accuracy analysis was conducted for the baseline mission and the effect of variations in baseline parameters was noted. Estimates of the initial position errors were made on the basis of other programs and published data. Deflection maneuver execution errors were examined and entry and descent path contributions to the dispersions were evaluated. Data are presented for errors in deflection radius, initial velocity, periapsis radius, deflection velocity increment, and deflection impulse application angle. The effects of atmosphere variations and uncertainty in ballistic coefficient are presented in Appendix H, Volume III.

2. Thermal Control Studies

The thermal control effort was broken into separate problems along the lines of mission phases. The interplanetary cruise phase was divided into a preseparation and postseparation phase, and the descent phase was further broken down by probe configuration: large, small, high cloud, and balloon. The descent phase dictated the probe design, and during descent the thermal design and structural design were so interrelated that they were performed together in a computer program.

The majority of the analyses were performed on the baseline design of the descent probes: a double-walled pressure vessel containing multilayer insulation in an evacuated annulus between the two walls, with a quantity of phase change material (PCM) added to certain individual components. An alternative design concept, using a relatively heavy insulation on the outside of a single-walled pressure vessel, was partially evaluated and shows possible advantages in weight, reliability, and producibility. Several areas were given a detailed examination, such as, the thermal control of individual science instruments, the prediction of average and local convective heat transfer coefficients, the mechanization of PCM, and the thermophysical properties of the Venusian atmosphere.

The results of the baseline design are as follows:

1) <u>Preseparation cruise</u> - Each probe requires 20 layers of ¼-mil goldized Kapton multilayer insulation on the outside of the biocanister, covered by a thin metallic shield with an α/ϵ of 2.75;
2) <u>Postseparation cruise</u> - The probes require a thermal control coating on the heat shield with a α/ϵ of 0.75/0.85;
3) <u>Descent</u> -
    a) <u>Large probe</u> - The large probe requires 0.8 in. of multilayer insulation and 6.3 lb of PCM,
    b) <u>Small probe</u> - The small probe requires 0.4 in. of multilayer insulation and 2.5 lb of PCM,
    c) <u>High-cloud probe</u> - The high-cloud probe requires no thermal control provisions.

Results for the optional missions are as follows:

500 mb Balloon - No thermal control provisions;

50 mb Balloon - The 50 mb balloon requires 1.0 in. of multilayer insulation and a 2.2 W thermostatically controlled heater.

3. Structural/Mechanical Systems

a. Aeroshell Structure - Data have been compiled for a variety of structural configurations and alloys, including ring-stiffened and honeycomb aluminum, titanium, and stainless steel. The information is available as a function of pressure for a range of aeroshell diameters from 3.0 to 7.0 ft.

The nature of weight sensitivity to pressure and size is such that increasing the ballistic coefficient by reducing the size results in a net reduction in structural weight.

The ring-stiffened aluminum data span the size and pressure range in the most consistent manner and are used in the probe designs of this study.

b. Descent Capsule Pressure Vessel Design - A conical pressure vessel has been selected for compatibility with terminal descent ballistic coefficients and aerodynamic stability requirements. Parametric studies were conducted using an equivalent volume, spherically domed cylinder and a detailed stress analysis performed on a conical probe to establish the validity of the approach. Weights were found to differ by less than 5%. The optimum design arrangement was found to be waffle-stiffened domes and a ring-stiffened cone frustum. The material selected is 6Aℓ-4V titanium.

The combination of the 150 Atm pressure and 900°F temperature of the V5M atmosphere model at a 6050 km radius was found to be slightly more critical than the 125 Atm, 985° combination at 6045 km radius in the MMC Lower atmosphere model.

c. Heat Shield Design - Heat shield data have been provided by JPL for 45° to 60° half angle aeroshells for a range of entry angles, velocities, ballistic coefficients, and entry vehicle geometries. Application of these data to the probes of this study results in forebody heat shield weight fractions, i.e., W_{HS}/W_{ENTRY}, of 10 to 15%. Adding a base cover heat shield increases the weight fraction to 14% to 19%. Due to the relatively flat slope (over the range of interest) of the heat shield unit weights as a function of ballistic coefficient, entry angles, and velocity, the heat shield design does not constrain the mission.

d. Instrument Integration Studies - Techniques for providing deployment of all the instruments have been developed for the double-wall insulated pressure vessel design. Attention has been given to cg location, installation problems, thermal control provisions, and minimization of the disturbance to the aerodynamic shape of the descent capsule. It is concluded that integration of all instruments is feasible but that the double wall, evacuated insulation design makes the problems difficult.

e. Decelerator Design Studies - Design data have been developed for both supersonic and subsonic decelerators. All decelerator designs used in this study were based on conventional-type parachutes and a tested ballute design. The deployment conditions for these designs are within the limits of present flight test experience for both Mach number and dynamic pressure.

4. Telecommunications

The key results of the analyses done in support of the telecommunications system design are:

1) Atmospheric propagation losses, attenuation, and defocussing, are acceptable (less than 3 db) out to 75° from subearth, but rise rapidly beyond this point.

The communications mask angle has been set at 70° for this reason, allowing 5° for targeting errors;

2) Fading due to multipath also increases as the angular distance from subearth is increased. Vertical polarization combined with antenna directivity to reduce the multipath signal level, and long constraint length coding to average over the highs and lows of the fading signal, are used to reduce this problem to a negligible level inside the 70° communications mask;

3) Position determination for the balloon probes is based on ranging and a measurement of the polarization direction of the signal transmitted from the balloon over a vertically-polarized antenna. Accuracy of the fix is estimated at 300 km or better. A position fix will be made periodically over a period of 7 or more days to track the atmospheric circulation patterns;

4) A flush-mounted annular slot antenna located in the top of the probe is selected for the limb probes. This is a vertically polarized antenna with the desired side-looking conical pattern. This is selected in preference to a circularly polarized antenna for two reasons. First, it improves multipath rejection, and second, it is not possible to build a simple flush-mounted antenna giving circular polarization at low elevation angles because of ground plane effects on the horizontally polarized component. A circularly polarized antenna would have to be raised some distance above the top of the probe.

5. Science

The major supporting analyses in the area of science studies included:

1) Definition of baseline atmospheric parameter range for entry and descent studies. A low density model that bounds the Mariner and Venera data was constructed (see Chapters II.C and II.H, Volume II);
2) Translation of the basic science questions into a set of observables or measurements that would answer the questions. Specification of the science mission requirements for accomplishing these objectives or observables (see Chapter I.A, Volume II and Appendix D, Volume III). Evaluation of the various missions for scientific accomplishment;
3) Science instrument mechanization and integration. Concepts for obtaining meaningful measurements of the atmosphere and clouds are discussed in Chapter IV, Volume II.

III. STUDY CONCLUSIONS

A. GENERAL

The science objectives identified in the contract statement of work are well satisfied by the baseline mission within the limitations of the specified available instruments. The requirement for observing atmospheric parameters over significantly different planet locations is also well satisfied by entering at the subsolar, antisolar, and polar target zones. The baseline mission represents a sound compromise between science compatibility and mission weight, complexity, and Launch Vehicle payload capability.

The two optional missions identified are essentially the baseline mission with increased science capability, using the full Launch Vehicle payload in the case of Option 2. The science performance of the baseline mission should be considered near optimum for the objectives and instruments identified; further improvement in scientific data return becomes increasingly difficult.

The Mariner configuration 20a (Mariner '69 modified in a previous study for a 1972 Venus mission) has proven to be an adequate base for the multiple probe Planetary Vehicle design. Significant modification requirements are few, and are defined in Chapter V.D of Volume II. A major change is the relocation and increased impulse required of the midcourse propulsion motor.

No designs exceeding the 1972 state of the art are included in the baseline mission configuration. The designs are, in general, not dependent on new technology developments. In some detail design areas such as pressure vessel seals, feedthroughs, electrical connectors, and provisions for maintaining clear windows for optical instruments, development is required.

Several mission alternatives have been identified during the course of the study that could alter the approach for system design and operation. One of these alternatives is the use of an externally insulated pressure equalized descent capsule canister for the large and small ballistic probes that descend to the surface. Another alternative design that may become available from other programs is the supersonic decelerator. Use of supersonic decelerators will improve the sampling altitude of the high cloud probe, and remove much of the constraint on targeting caused by low entry angles.

Because the atmospheric objectives are answered in a manner that is difficult to improve on without major concept changes, some consideration may be applied to the addition of an expanded scope of objectives. These expanded objectives could provide significantly more science data about the planet rather than spend the entire Launch Vehicle capability on more atmospheric instrumentation. Expanded scope measurements could include those compatible with orbiters or landed capsules.

B. SCIENCE ACHIEVEMENT

The measurements obtained with the baseline mission entry probes would provide the basic information necessary for an understanding of the physics, chemistry, and dynamics of the lower atmosphere and clouds of Venus. How complete this understanding will be will depend to a large degree on the results of the measurements that will most likely raise new questions. In any event, the baseline mission would contribute to the answering of all the basic questions posed as scientific objectives for the next generation Venus mission (see Appendix B-1 and Chapter I.A, Volume II).

Figure 15 summarizes the current knowledge of the atmosphere of Venus along with some speculations concerning the lower clouds. The regions of most importance to the four general science objective categories are indicated at the right. The objectives require coverage at *all* altitudes; the ranges shown are of primary interest. The upper atmosphere objectives require coverage through the ionosphere peak at about 6190 km down to about 6170 to 6180 km. The regions of most interest for the circulation and cloud measurements extend from above the cloud tops down through the tropopause and layered structure indicated by Mariner 5 to about 6085 km. The regions above and below the Venera coverage are the regions of primary interest for the atmospheric structure and composition because they have not been investigated previously and are more relevant to the questions.

The instrument altitude sampling resolution required to meet the detailed objectives over these ranges is discussed in Chapter I.A, Volume II. Briefly, most of the instruments require a sample every 200 to 500 m near the cloud tops; the mass spectrometer, evaporimeter/condensimeter, and the radar altimeter require measurements every 1000 to 2000 m through the cloud tops. The cloud composition instrument requires a sample every 2000 m through the region of the cloud layers indicated by Mariner 5 (between 6110 km and 6085 km); and a sample every 5 km is sufficient above the tropopause and below 6085 km.

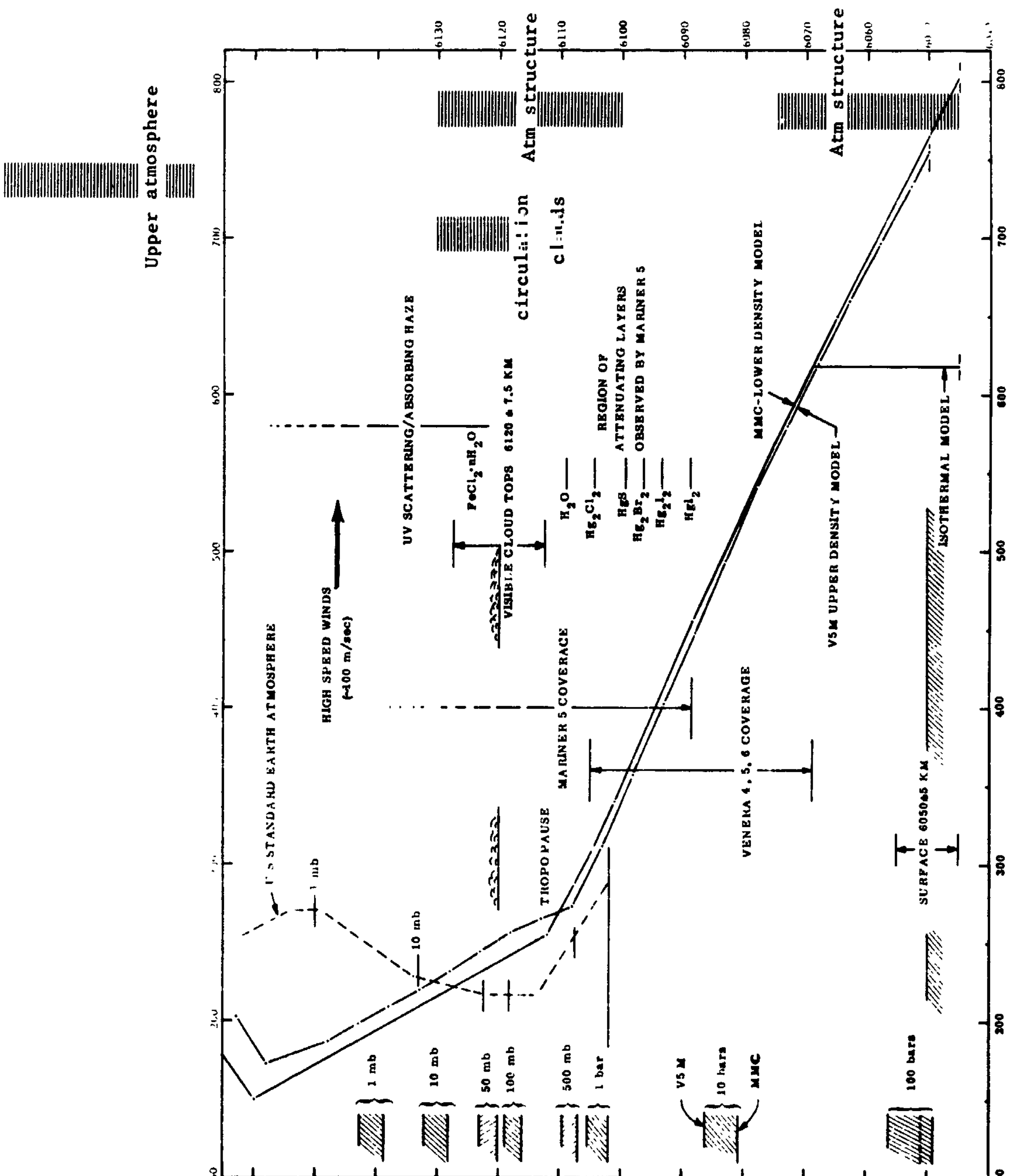


Fig. 15 Venus Temperature Profiles

Figures 16 thru 18 illustrate how well the baseline mission probes meet these requirements through the lower atmosphere. The large subsolar probe carrying all available instruments obtains comprehensive radius referenced profiles from above the nominal cloud tops to the surface with better than nominal altitude resolution over the entire trajectory for all instruments. The cloud composition experiment is the one exception because of its minimum sample analysis time of 300 sec. The instrument does obtain better than nominal altitude resolution through most of the lower cloud layering however. The large probe's only other deficiency is that it is deployed above the nominal clouds, but below their upper uncertainty limit (6127.5 km). Both of these deficiencies are rectified by the high-cloud probe as seen in Fig. 18.

The high-cloud probe does much more than supplement the large probe cloud measurements. Its low descent velocity and position near the limb (as seen from earth) make the wind shear and turbulence measurements (transponder and three-axis accelerometer) extremely sensitive through the regions near the cloud tops and tropopause where the circulation is expected to be strongest.

The two small probes provide information on essentially everything the large probe does. While they lack the cloud composition, radar, and cloud particle size instruments of the large probe, information on the cloud composition is obtained from the mass spectrometer and evaporimeter/condensimeter. An altitude reference is given by the pressure measurements (having referenced pressure to altitude with the large probe) and a short range (300 m) radar indicates surface approach. The nephelometer may provide useful information for determining the particle size in the clouds as well as determining their vertical structure. The altitude sampling resolution obtained with the small probes (Fig. 17) is better than nominal at all altitudes except between 6100 km and 6090 km just after parachute release. The large probe resolution is best through this region, while the small probes resolution is better than the large probes above 6100 km.

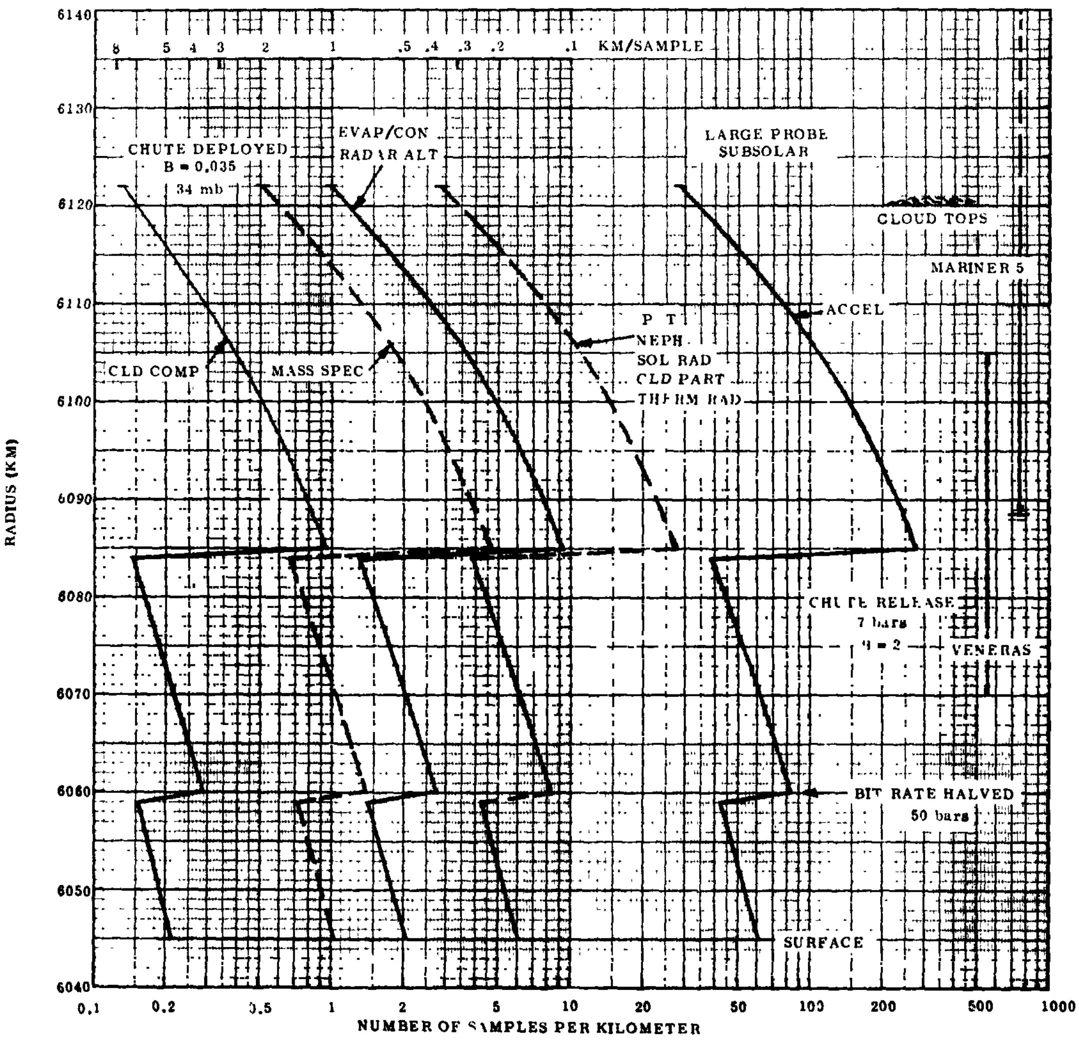


Fig. 16 Altitude Sample Resolution, Large Probe

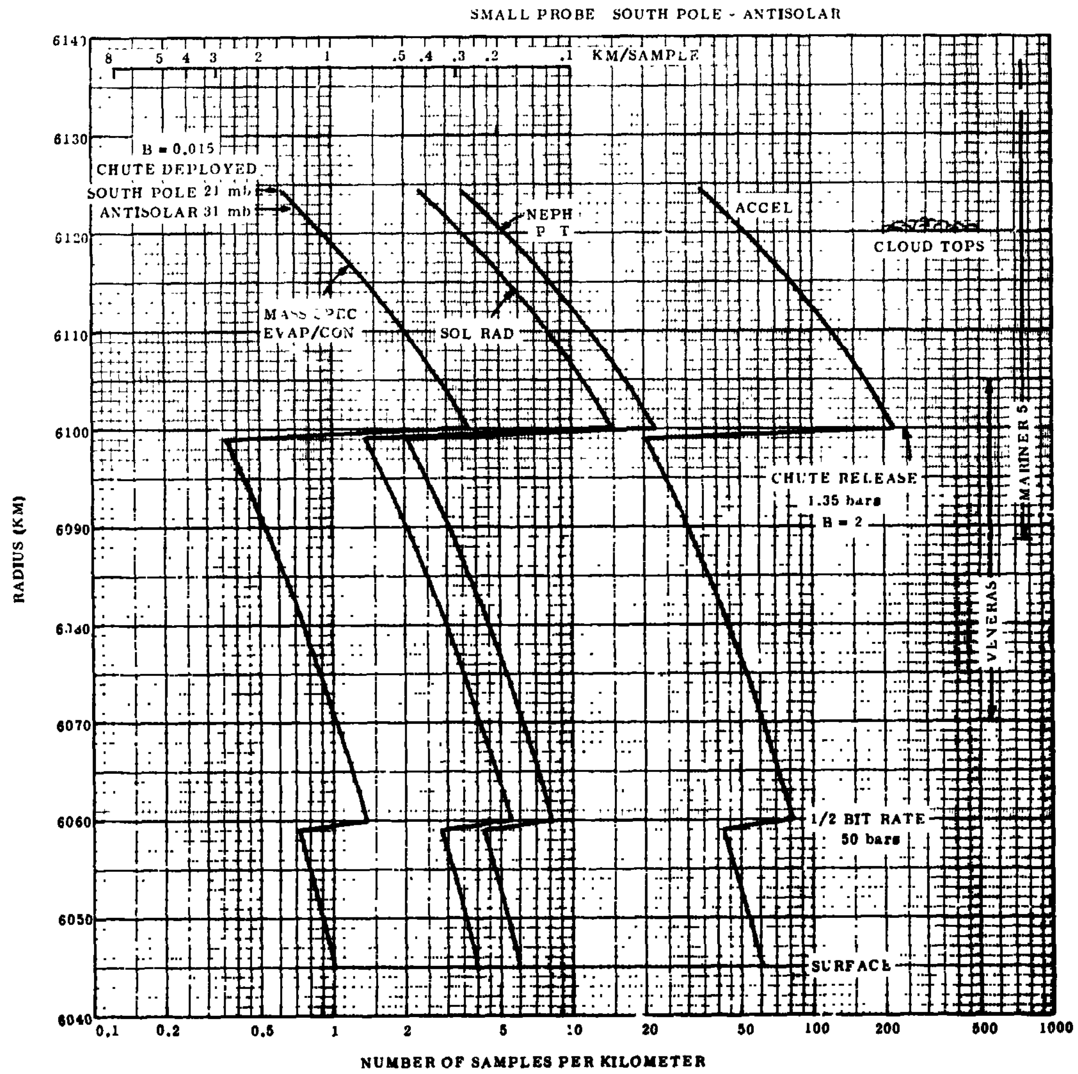


Fig. 17 Altitude Sample Resolution, Small Probe

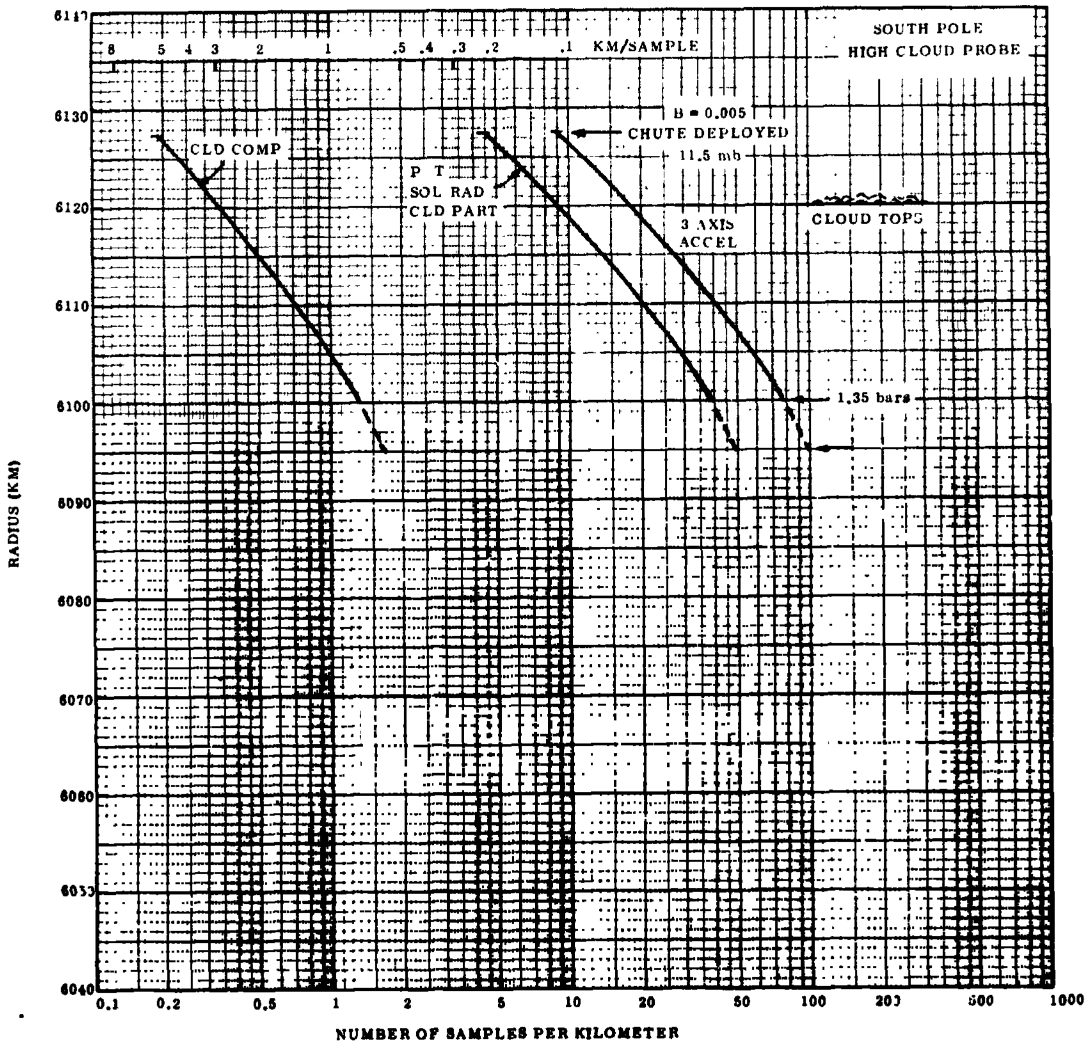


Fig. 18 Altitude Sample Resolution, High-Cloud Probe

Thus, the four probes of the baseline mission complement each other, providing comprehensive altitude coverage from above the cloud tops to the surface over the three most different regions on the planet -- the subsolar, the polar, and the antisolar regions. The horizontal coverage of the baseline mission also complements the coverage of previous missions as shown in Fig. 19.

The only deficiency of the baseline mission concerns its adequacy for determining the general circulation pattern from a series of localized wind measurements. An unambiguous determination of the circulation requires tracking of a balloon for an extended period of time (days). To resolve this difficulty, Option 1 on the baseline mission adds a 500 mb balloon to the baseline complement of probes.

The determination of the circulation is further improved in Option 2 by the addition of two balloons; one at the 500 mb level as in Option 1, and one at the 50 mb level near the cloud tops where the strongest circulation is expected. This option also improves the determination of the cloud structure, composition and wind variations over the planet with the addition of a second high-cloud probe near the antisolar region. Thus, Option 2 represents an "ideal" science mission from the standpoint of answering the basic questions as completely as possible within the constraints of the mission and the available instrumentation.

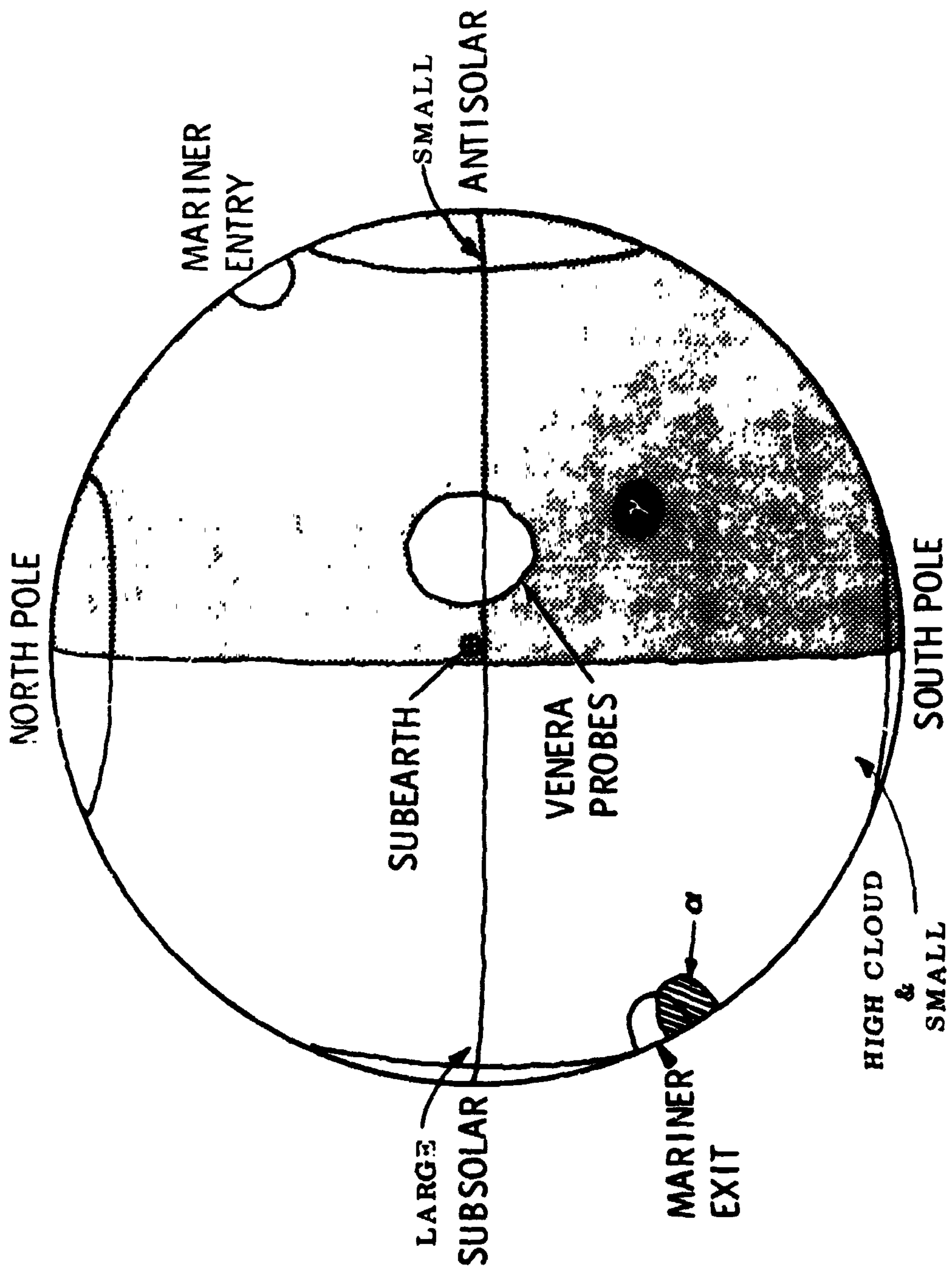


Fig. 19 Science Target Zones

C. TRAJECTORY CONCLUSIONS

The trajectory conclusions are predicated on two principal constraints: the Launch Vehicle is Titan IIIC, and direct communications between the earth and the probes will be used. One further consideration from the science area is the identification of the subsolar region as a prime interest area. To achieve direct communications to a point within 20° of the subsolar point requires an arrival date of November 5, 1975, or later. The science experiments should be within 20° to 30° of the desired target point to achieve reasonable value of data yield and the closer to the actual point the better. The direct communications link to the planet surface is limited to the area within 70° of the subearth point by link losses.

The Launch Vehicle considerations indicate that an October 31, 1975 arrival date will minimize C_3 values over a 20-day launch period and yield a payload of 4000 lb. The entry velocities will not exceed 10.8 km (35,400 fps). In this case the communications mask is approximately 25° from the subsolar point. This condition is acceptable to the science advisors as a worthwhile tradeoff and a Type II trajectory arriving on October 31 is the selected interplanetary path. The 20-day launch period extends from May 15 to June 4, 1975. The communications range is 95×10^6 km. One additional advantage is noted for this arrival date. The location of the V_{HE} moves only about 7° during the launch period, and therefore reduces the retargeting requirements on the midcourse and deflection maneuvers.

At planetary encounter the spacecraft can follow a flyby or direct impacting path. Little differences are noted in the two paths. The flyby trajectory requires about 40 m/sec more velocity increment in each deflection maneuver, but results in entry angles of attack of up to 15° less than those resulting from the direct impact case. The direct communications link is not affected. The error sensitivities are a function of periapsis radius and are greater than the impacting case $\left(R_p = 2800 \text{ km}\right)$ at $R_p \lessapprox 9000$ km. To assure missing the planet a flyby path will probably always be at more than 12,000 km radius, and therefore will result in greater trajectory dispersions. The flyby trajectory plane will generally be oriented differently than the impacting spacecraft plane for accuracy reasons.

The deflection strategy uses deflection angles of 20°. The 20° angle is near the smallest acceptable value from the error sensitivity standpoint and near the maximum value to achieve reasonable entry angles of attack ($\alpha < 50°$). The deflection velocity increment generally is applied as a speedup maneuver to improve pointing and propulsion system installation. However, for the balloon probes the maneuver is a slowdown (retrothrust) maneuver to make the balloon entry last and provide a long period of uncontested communications time. The deflection maneuver is selected to achieve the desired targets and provide a staggered entry so that no more than two probes use the two-way communications links at any one time. In implementing these maneuvers. the actual deflection times must be spread out to permit spacecraft maneuvers to properly point the probes. Variations of up to ±2 hr about the nominal deflection time do not affect the deflection or entry parameters.

The entry phase of flight has as its goal the deceleration to subsonic velocities above the cloud tops. The V5M atmosphere yields entries that easily accomplish this goal. The lower density model atmosphere is more constraining and requires low entry angles (-25°) and low ballistic coefficients (0.2) to reasonably achieve subsonic velocities above the cloud tops.

Descent from initial deceleration is near vertical at terminal velocity. The V5M atmosphere yields longer descent times than the lower density model. However, staging of probes at a fixed pressure value reduces the descent time differences significantly from those that result from equal altitude staging.

Target point dispersions are generally less than ±6° in downrange and ±4.0° in entry path angle. The crossrange dispersions are about one half the downrange dispersions.

D. STRUCTURAL/MECHANICAL SYSTEMS

It is concluded that probe types involving a single stage subsonic decelerator system can be designed with existing technology and are entirely feasible. Major entry vehicle and descent capsule systems, other than the heat shield, require little additional development. Heat shield weight fractions are low enough, ∿15 to 20%, not to constrain the missions. However it was found that neither of the two materials used in the study is optimal for all probe types needed. In certain other areas, including pressure vessel seals, feedthroughs, electrical connectors, as well as in the area of provisions for protecting external optical surfaces, development is required.

Development of supersonic decelerators does not appear to be essential unless a need is established for high-cloud data at targets requiring steep entry angles e.g., the subsolar point. However, the availability of such devices would add flexibility to probe design and science deployment altitude selection.

The use of an evacuated double-wall pressure vessel provides acceptable system weights, but makes the task of integrating the science instruments difficult and results in some uncertainties in insulation performance because of the penetrations. The use of external insulation appears to afford equal or lower weights and would significantly relieve the integration and producibility problems. A third concept, that of equalizing the pressure in the instrument compartment, also looks attractive in that it avoids the pressure vessel sealing problems. It would, however, introduce the problem of development and qualification of pressure resistant electronics.

The use of a high-cloud probe as a special type carrying a small payload is quite desirable because: (1) the weight and complexity penalty to achieve the initial deceleration at high altitudes with a large payload is prohibitive; and (2) the weight of the large parachute required to establish the descent rate required after initial deceleration is a large fraction, $\sim$50%, of the payload.

Integration of probe systems with the Mariner spacecraft is feasible, however a major change is required in the relocation and increased impulse capability of the spacecraft propulsion system. Lesser modifications are required in the attitude control, thermal control, and structural systems.

E. TELECOMMUNICATIONS AND POWER

The atmospheric attenuation and defocussing losses are not prohibitive out to about 75° from subearth, reaching 3 db at the surface for the worst-case atmosphere at this distance from subearth. Losses rise rapidly beyond this point. Accordingly, a 70° communications mask angle was selected, allowing for a 5° targeting error. Bit rates are cut in half during the lower portion of the descent to offset the effects of these losses.

Values used for the nominal and worst-case zenith atmospheric attenuation are based on radar observations, and are believed to be reasonable. However, there is some uncertainty in these values. Large errors in these values could have a significant effect on the mission.

Multipath effects are controlled by long constraint length codes to average over the highs and lows of the fading signal. Antenna directivity, combined with vertical polarization for the limb probes, is used to minimize the multipath signal strength. Vertically polarized annular slots are recommended for the side-looking antennas required for the limb probes.

The balloon position is determined using ranging combined with observations on earth of the polarization direction of a vertically polarized balloon transmitting antenna. This polarization measurement cannot be made inside a circle of 5° to 10° radius centered on the subearth point. Outside this region the position uncertainty is estimated to be 300 km or less.

Transmitter size varies from 8 to 20 W on the various probe types, and bit rate ranges from 20 bps to 120 bps. Solid-state transmitters are assumed. Power systems are based on silver-zinc batteries. These are supplemented by solar panels on the balloon probes for extended lifetimes. Solar panel designs are based on worst-case estimates of light levels at the balloon float elevations in and below the clouds.

Data formats and block diamgrams were prepared for all of the probe data handling subsystems to determine how readily the data system could be designed to handle the sample rates and instrument mix. Assuming a reasonable interface can be negotiated for the actual instrument design (some of the instruments do not presently exist), there are no significant problems in providing a data handling system using data buffering for the more complex instruments. The data formats will need to be optimized for the error correction, and detection encoding method selected for the final design as well as for the actual instrument output when these parameters can be defined.

By dividing the probe sequencer functions into two phases -- coast and entry -- a low-power tuning fork type of clock can be used to measure the approximately 11-day coast period required after separation from the spacecraft. A digital counter (which can easily be set before launch and started when the tuning fork clock has run its course) can provide the run out time variation required from probe to probe to despin and start the entry sequencer. In this manner both low power and commonality of equipment can be obtained. A further advantage of separating the probe coast sequence function is that the coast sequencer does not have to be designed to operate through the entry environment.

F. MISSION OPERATION

1. Multiple Probes

The multiple probe mission has been shown to be a feasible approach toward obtaining planetwide data in a single (relative) time span. This is important toward understanding the distributive characteristics of atmospheric composition, circulation, and clouds. The support of, and separation of multiple probes is complicated but entirely feasible. Missions with similar capsule separation functions have already been highly successful.

2. Flyby versus Direct Impacting Spacecraft Modes

The selection of a spacecraft operational mode was not to be made during this study. However, the following information, which will effect that decision, is presented:

1) Deflection impulse for the direct impact mission is lower, resulting in a lower total mission weight. However, using the Titan IIIC Launch Vehicle has eliminated sensitivity to the level of additional propellant weight required for a flyby mission;
2) The upper altitude science instruments located on the capsule adapter truss for the impacting mission, would require relocation in an entry probe for the flyby mission. This would result in a weight increase for that probe (large ballistic), but would not significantly influence the system operation or capability;
3) Biological protection must be provided for all entry items for the impacting mission. Since the individual biocanisters will enter, they must be decontaminated externally and internally. This has been provided for by a large biocanister that encloses all entry items that can then be sterilized externally by introduction of ethylene oxide. This large biocanister will remain with the final Launch Vehicle stage. The flyby mission does not require this large biocanister because the individual biocanisters will not enter the planet's atmosphere.

It is important to note that although consideration of the impact of sterilization upon the Mariner spacecraft was not part of this study, it will certainly be the most prominent factor in the decision if existing quarantine restrictions are still in effect.